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TWO CASES OF SPLENECTOMY FOR SPLENIC ANEMIA

A CLINICAL LECTURE, JAN. 21, 1920, TO THIRD-YEAR STUDENTS, TELLING AN OLD STORY

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AND

A REPORT ON THE PATHOLOGIC CHANGES IN SPLENIC ANEMIA

(Written in 1900, but not Published)

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Gentlemen:—We went over together last week some patients with biliary disorders showing degrees of jaundice. One of them — Mary Jones, as you will recall — had a history of frequently recurring attacks of cholelithiasis over a period of nine years, but had never before been jaundiced. As her jaundice was rapidly fading, we arrived together at the conclusion that the common duct would be found free.

You saw the patient operated on subsequently by the resident, Dr. Cutler, and will remember that at an early stage of the procedure digital palpation led him to believe that there must be a stone in the common duct. After removing the gall-bladder, which was full of stones, he found that the impression of a deeper stone had been given to the finger by a pancreatic nodule which partly enveloped the lower portion of the duct.

It is well for you to bear in mind that this is not an uncommon observation, though less common now, I am sure, than in former days before it was pointed out — first by Mayo Robson, I believe — that chronic pancreatitis was a common accompaniment of cholelithiasis and often produced a degree of induration frequently mistaken on palpation, particularly through the inadequate openings then made, for malignant disease or for a large common duct stone.

Now, Mr. B——, will you tell me what you notice about this patient, named Alvin Landers, whom we may uncover for your inspection?

Third-Year Student.—"He appears to be jaundiced, but in his inguinal region there is a newly healed wound which suggests an operation."

Yes, he has a yellowish tint to his skin apparent also in his conjunctivae, quite unlike the color, as you will recall, of the gallstone cases you saw a week ago. But do you think this incision could have any relation to the skin discoloration, and, if not, what does it suggest to you?

Student.—"It looks like a recent hernia incision."

It is, I believe, and we will now hear the essential facts of his clinical story from Mr. A——.

Fourth-Year Student (clinical clerk).—"The patient is 35 years of age, a restaurant keeper, who entered the hospital January 1. He tells of having a small 'lump' in the right groin for five years, which gradually increased in size, and he has worn a truss for three years. The evening before admission, while straining at stool, the 'lump' suddenly enlarged and could not be reduced. Vomiting set in during the night; a physician was called, but he was unable to reduce the hernia and so sent him to the hospital the next morning. A diagnosis of strangulated indirect inguinal hernia was made. The hernia was immediately operated on under local anesthesia, and though the bowel was much discolored, the vessels were not thrombosed, and sufficiently good circulation returned into it to justify its replacement.

"On admission it was noticed that he was jaundiced, and it was learned that this condition had been present for fifteen years, ever since an attack of pain in the right upper quadrant, accompanied by nausea and vomiting which confined him to bed for six months. He states that during that illness he had dark-colored urine and clay-colored stools, and that he subsequently passed over 200 gallstones, but refused a proposed operation because of his mother's objections, for she is said to be even more yellow that he, and has had jaundice herself for many years and has done well without operation."

Now, Mr. B——, before we go into this story any further, what impression have you perhaps gained regarding this patient?

Third-Year Student.—"I think he must have some other trouble than the rupture for which he came to the hospital."

Yes, undoubtedly he has, although, as you have doubtless been told before this, it is the safest plan to attribute the symptoms which a patient presents to one underlying cause—a symptom complex—rather than to look for multiple causes. But here the conditions are somewhat different—an exception which proves the rule—for we have an acute complication on the part of an old rupture in a patient with some underlying trouble, and what do you think it may be?

Third-Year Student.—"It is very peculiar that he should have had such persistent jaundice if due to gallstones, and also that his mother has gallstones and jaundice."

It is peculiar, and, what is more, as Mr. A—— could tell us, we have since learned that he also has a brother who has chronic jaundice. Then, too, you have noted that his jaundice has a curious lemon-yellow tint, and, what is more, he has no evidence of bile in his urine, nor are his stools pale in color. Is it not the usual thing in cases of icterus to find bile in all the body fluids?

Student.—"I think so."

Yes, in all the body fluids except the cerebrospinal fluid, for, as I have told you, the choroid plexus, unless diseased or injured, is a filter so effective as to prevent the passage from the blood of all but a very few chemical substances. But here, with exception possibly of the blood, the fluids are not stained, not even the urine, and it is therefore what is called an acholuric jaundice. Now I may be trespassing on a subject you have not as yet covered and would like to ask the class whether they have any idea what may be wrong with this man in view of his history, and will ask those to raise their hands who know what we are likely to find on palpation of the abdomen. (Many of the class responded.) Some of you, at least, appear to have met with this condition in your medical lectures, and so, Mr. B——, will you let us know what you feel in this patient's belly?

Third-Year Student.—"He has a large mass on the left side which descends with respiration and I think must be his spleen. It reaches the level of the navel."

Yes, and what would you like to know next?

Third-Year Student.—"The findings in his blood."

Clinical Clerk.—"The blood shows 2,800,000 reds, 11,000 whites, and 60 per cent. hemoglobin. The differential is not remarkable—67 per cent. polymorphonuclears, 25 per cent. lymphocytes, and 20 per cent. eosinophils. The red cells do not show any departure from normal, but the fragility test made by Dr. Kebajian shows beginning hemolysis at 0.75 per cent., as against 0.46 per cent. for the control."

What, then, might be your diagnosis in this case, Mr. B——?

Third-Year Student.—"Hemolytic jaundice, probably of the congenital type."

And would you advise any treatment for the condition?

Third-Year Student.—"We have been told by Dr. M—— that splenectomy is of great benefit in these cases."

Yes, I think that is the prevailing idea, particularly regarding this family variety of splenomegaly. It is the type to which attention was first directed, I believe, by the students of Minkowski, of Chauffard

and of Vaquez, and it has been variously called congenital (or familial) hemolytic jaundice (or icterus), as you will.

I do not know what others have told you, but I do not believe that it is at all clear whether the underlying fault in these conditions lies with the blood or with the spleen, or possibly elsewhere. The fact that symptomatic improvement has followed splenectomy speaks in favor of a splenic origin; others ascribe the disorder to a primary change in the blood, to the low osmotic resistance of the erythrocytes, or possibly to an imperfect blood formation or to some form of hemolysis of normal corpuscles due to an unknown chemical influence. This is a little vague, perhaps, but then, vagueness still characterizes our knowledge of blood-forming organs. Certainly, if the disease is hereditary it probably obeys Mendelian laws, and therefore should be much more common in affected families than the presence of icterus and splenomegaly would indicate, so that we may assume there are many milder cases unrecognized having neither jaundice nor large spleens. In short, the disease may possibly exist in the absence of the two outstanding symptoms which gave it its name. Nor is this unique.

Then, too, authorities are still equally indefinite in regard to the cause of the jaundice in the absence of cirrhosis or obstruction of the bile passages. Some ascribe it to the clogging of the biliary capillaries by an excess of viscid and highly pigmented bile, a consequence of blood destruction. On this I cannot pass.

This whole subject is one in which I am at this moment more interested from the standpoint of your fellow student than from that of a teacher, and as I have refreshed my mind regarding it before coming to this exercise, I will show you, for your benefit, the volumes I consulted. Here is a book you will find very useful, particularly because of its brevity of description and valuable bibliography. It is Barker's Clinical Diagnosis of Internal Diseases; and in this second volume there are a few pages devoted to the diseases of the spleen, where you can get your essential facts, up to 1916, very quickly and very briefly. You are given also, some of the more important references—in the author's estimation at least—so that you may run our prevailing ideas down to their source of origin. Such a treatise as this can serve you as a short cut to the Index Catalogue and Index Medicus, where, at your stage, you are likely to be swamped by the immense number of titles on a given subject.

But possibly this volume should have come first — the last edition of Osler's Principles and Practice; and, as I have told you before, it is perhaps the best jumping-off place for most subjects, whether surgical or medical, that you may wish to look up. You will find here under "Jaundice" a note about the hemolytic varieties, and the fact

that it was Chauffard who first pointed out the increased fragility of the red corpuscles — a note also on a hereditary form of icterus in infants, first described by Glaister, as well as this acholuric form before us which Minkowski reported. However, Osler does not feel that the disease is necessarily familial, though some writers have attempted to subdivide the cases into acquired and inherited types.

And there is another thing I may call to your attention which I had forgotten — namely, that in the icterus of the new-born, in contradistinction to other forms, the central nervous axis may be bile-stained, though I do not know whether this is also true of the cerebrospinal fluid in these cases, contrary to what I have told you.

Let us now turn to the section on the spleen, in the diseases of which Dr. Osler became interested, and to which he made important clinical contributions. Here you will find in the section on "Primary Splenomegaly with Anemia" a description of splenic anemia or Banti's disease, which he defines as "a primary disease of the spleen of unknown origin characterized by progressive enlargement, attacks of anemia, a tendency to hemorrhage, and in some cases a secondary cirrhosis of the liver with jaundice and ascites," and please observe that he says further, "The spleen itself is the seat of the disease, as is shown by the fact that complete recovery follows its removal."

You will note that the jaundice shown by Alvin Landers here has been an early and not a late symptom of his malady, and that there are no evidences of hepatic cirrhosis, nor have there been hemorrhages. Otherwise this brief description might cover the case of our patient well enough.

Osler, as you see, laid great emphasis on the tendency to hemorrhage, particularly hematemesis, as a special feature of Banti's disease, with recurring attacks often over many years, and he points out that the diagnosis of ulcer of the stomach may consequently be made. As I shall return to this again, I may read that "the bleeding may be of great severity. On several occasions one of my patients was brought into the hospital completely exsanguiné; in two the hemorrhage proved directly fatal; in a third the hemorrhage proved fatal ten days after a successful removal of the spleen . . . One patient had splenomegaly with repeated hemorrhages, and has now (1912) had more than twelve years of good health after splenectomy."

Again, under "Hemorrhage from the Stomach," Osler gives as causes passive congestion and splenomegaly, for he says (page 507) that "gastrorrhagia is by no means an uncommon symptom in enlarged spleen, and is explained by the intimate relations which exist between the vasa brevia and the splenic circulation." I quote this because the source of hemorrhage in these cases is another matter to which we will return.

Now let us go a little farther and turn to one of the systems of medicine which you will find in the school library if you do not happen to have succumbed yourself to a sales agent. Having already spoken of Osler's relation to the subject, you may turn to Modern Medicine or to Allbutt and Rolleston's System, in which there is also an exceedingly good chapter on diseases of the spleen, where you will find a still more elaborate presentation of the topic.

And lastly, to pursue the subject still farther without going to original sources, we may turn to some work of monographic form, and the most recent that I know of in English is this volume by Pearce, Krumbhaar and Frazier, on the spleen and anemia, which Dr. Cutler has loaned to me, so that here again, and proportionately in still greater detail, you will find this general topic gone into.

Thus in looking up a subject one proceeds, from a brief synopsis, to a textbook, to such short monographs as occur in standard system of medicine, to separately printed and larger monographs, and as a last court of appeal to the general literature of our journals through the agency of our great indices, and the results of so doing once on a time, fill this filing box as I shall tell you later; for twenty years ago, I would have had less need of consulting recent literature before coming to an exercise on this subject.

At that time this case would probably have been called primary splenomegaly or splenic anemia, or possibly splenic anemia with icterus, in view of this additional symptom; but of late years various types of splenomegaly with varying forms of anemia have come to be separated off, for one reason or another, from the cases which, in 1900, would probably have been grouped together — and may come to be again.

One might give a historical résumé of this process of separation somewhat as follows:

At first when we knew far less even than now of splenic function, enlargements of the organ were of course well recognized. They, for the most part, were secondary manifestations of some known disease process. Thus, we may dismiss, in our present consideration, the acute splenomegalies of various febrile states, the large spleen of chronic malaria and kala-azar, of syphilis, tuberculosis and echinococcus, the enlargement due to venous stasis of cardiac or hepatic origin.

A second step, and a most important one, was the recognition by Virchow and others of a splenic enlargement associated with a leukemia.

A third chapter would properly record the recognition of cases not due to the ordinary causes given above nor associated with an increase of white cells in the blood and therefore called "pseudoleukemias" by Cohnheim.

Then as a *fourth step* came Banti's first monograph in 1883, describing splenic anemia which was withdrawn from the nonleukemic splenomegalies, and at about the same time in France came Bruhl's papers on splenomégalie primitive. Both Banti and Bruhl, doubless provisionally, included numerous allied disorders, and Banti, in the belief that the spleen was the seat of the disease, advocated its removal.

As a *fifth step,* Gaucher separated off from splenic anemia of the Banti type a form with a peculiar histologic picture, characterized by masses of endothelial cells in the spleen and by hypertrophy of the liver. At about the same time —

A sixth step — a side step possibly — was taken by von Jaksch, who gave the name pseudoleukemia infantum to a form of splenic anemia which had been recognized in infants even before his time.

And then, finally, this disease, hemolytic jaundice, was separated off, and some are attempting to split this up into acquired (Hyem-Widal) and familial (Minkowski-Chauffard) types. This is the sort of thing that usually happens, and we are probably not through yet with these clinical distinctions, though probably many of them have much in common, and if Banti disclaims this progeny for splenic anemia, they at least were hatched in the same pseudoleukemic nest.

Now I wish to approach from a different angle these conditions of splenomegaly with anemia, in the surgical aspects of which I was once greatly interested.

STUDIES FROM OLD CASE-BOOKS

I shall take advantage of the occasion to speak to you of the value of case records and why it is we put the names of these patients on the board, and keep referring to them, because as I told you early in your year I wanted you to remember each of these clinical cases that you see, as patients, rather than merely as examples of some given symptom, such for example as jaundice in this man who has just gone out.

I have brought in here, to show you, a volume entitled "Studies of Old Case-Books," by Sir James Paget, whose life I hope all of you will some day read. The book contains accounts of some odd cases and conditions, with chapter headings such as "Diabetic Gangrene," "Ununited Fractures in Children," "Use of Will for Health," and so on, but what I want to quote are some paragraphs from his preface. He says:

> Few things of the kind seem to be more useless than old case-books. To the writer himself they may have some value and even great personal interest: he may profitably study himself in them as well as some of the facts which he has recorded.

Then he goes on to say:

> Thus as one looks through volume after volume, they seem to prove nothing but a waste of time, till one reflects that the present use of old case-books is no just estimate of their value in past years. For, to say nothing of the materials they may have supplied for work already done in lectures or in books and papers published at various times, they were among the very best means of self-education. The habit of recording facts is nearly essential to the habit of accurately observing and remembering them. That which we intend to record we are bound and may be induced to observe carefully, and the very act of carefully recording is nearly equivalent to a renewed observation. Thinking of this and of their personal interest to myself, I ought, perhaps, to have been content with the good service that my case-books have rendered to me and with the hope that they have been, in some measure, indirectly useful to others.

Now your attention has been called to this old volume of Paget's, because I wish to show you the accumulations which I have here of two old case reports concerning which I have much the same feeling that he has expressed in the quotation I have read to you. I show them to you also because I want you to learn to accumulate facts and material for yourselves through what you may learn in your various clinics and in your use of the journals in the library which I have so often urged you to get in the habit of going over. If you do nothing more than to jot down references to these articles, to which I have called your attention, and to put them with the notes which you must have already taken down about splenic diseases, together with one or two case reports of patients that may have been shown to you, like Alvin Landers this morning; and if you will keep this little collection of your own up to date by occasional additions from what you run across in your reading, you will build up a textbook of your own — one very much better than anything you can buy bound in covers, which must necessarily quickly become antiquated. By this means, when the time comes to need them, you will be able to recall your facts infinitely better than in any other way.

This old filing box which, until this morning, had certainly not been opened since 1910, is labeled "Spleen," and it represents some ancient accumulations regarding this topic which is under consideration, and I will tell you the story.

There came to the Johns Hopkins Hospital, March 9, 1898, a man, aged 33, C. D. B. by name, a farmer from Fincastle, Va., complaining of dyspepsia, and hemorrhages from the stomach and bowels. These he had had for nine years, the loss of blood at times having been sudden and very profuse, the attacks coming possibly once every twelve months. I remember him as a little fellow with a curious brownish coloration of the skin and a big spleen which was taken to

be an ague-cake doubtless in view of his place of domicile. He had a marked anemia, with hemoglobin of 25 per cent., about 3,000,000 reds, and a leukopenia of 2,800 cells. His gastric examination (this was before the days of bismuth roentgen-ray studies you will observe) showed a slightly dilated stomach with visible peristalsis, and a test meal showed a considerable hyperacidity. He was discharged, and returned to the hospital again on October 26, with his blood picture somewhat improved. A presumptive diagnosis had been made of bleeding peptic ulcer and he was transferred to the surgical service for operation.

Being the resident surgeon at the time, the case fell to my lot, but it was just at this period, as I remember it, that the first edition of Allbutt's System was published. I had invested in a set of the volumes and by chance had read Samuel West's article in Vol. V, p. 539, on splenic anemia. The condition seemed to fit the case of this man so exactly that I remember going over to Dr. Osler's house with some needless trepidation, the evening of the patient's transfer, to ask him if he did not think it was possibly a case of splenic anemia, and if I found no sign of pyloric ulcer would he mind letting me take out the man's spleen, because there had been one or two promising cases referred to by West. As was characteristic of him under such circumstances, he said, "Go ahead, young man, and do what you think best."

So the next day I made a primary exploration on the right side, found nothing, and then proceeded through a new incision to take out his spleen. It was very adherent, and I had a good deal of difficulty from bleeding during the separation of the adhesions under the diaphragm, but, nevertheless, in spite of his anemia, he recovered.[1]

There is a tradition, as you know, in most clinics, that when rare conditions turn up they often come in pairs, and while this Mr. C. D. B. was still in hospital, another patient, Mr. W. H., 30 years of age, was admitted to Dr. Osler's wards[2] with a very similar history: a large spleen extending to the umbilicus and several attacks of profuse hematemesis occurring over an eleven-year period. The blood picture was very much the same, there was the same muddy brownish tint to the skin, and he complained similarly of some upper abdominal soreness.

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1. The case was subsequently referred to in all of Osler's three papers: (1) "On Splenic Anemia," Am. J. M. Sc., January, 1900, Case IV; (2) "Chronic Splenic Enlargement with Recurrent Gastro-Intestinal Hemorrhages," Edinburgh M. J., May, 1899, p. 447, Case II; (3) "Anemia Splenica," Tr. Assn. Am. Physicians, 1902, Case IV.

2. Osler refers to him as Mr. A. B. in his first paper, Case V, second paper, Case III, and third paper (after operation) Case V.

This man also was operated on, and in addition to the large spleen there was found some ascites and a slightly cirrhotic liver. The same surgical difficulties were encountered from dense adhesions due to a perisplenitis, and I well remember his being kept in the operating room inverted on the table until the following day, as it seemed unsafe to move him.

He made an excellent operative recovery and his wound healed; but on the tenth day he had a sudden profuse vomiting of dark blood, fully 2 liters or more in amount, and died almost before the attendants could reach his bedside. At autopsy it was found that the bleeding had come from an esophageal varix, and I pass around this very beautiful water-color made by Mr. August Horne, one of the artists then in Dr. Kelly's clinic, which shows the lesion.

So far as I have been able to determine this morning in looking over these accounts of splenic anemia, Dr. Osler in particular laid stress on hematemesis, and his impression was doubtless colored by these early cases. So far as I am aware, also, this was the first and perhaps the only case in which the bleeding was shown to come from an esophageal varix, for I have read you the note in Osler's Practice in which he ascribes the hematemesis to capillary hemorrhages from the stomach. Esophageal varices of course are common enough and may occasionally be a source of fatal hemorrhage in extreme passive congestion either of cardiac or hepatic origin. In both of these patients, however, that I have referred to, the changes in the liver were insignificant, at least in gross appearances, for though in Banti's disease proper there is a terminal stage of cirrhosis with ascites, this was not apparent in Case I, and but very slightly in evidence in Case II. Disease of the portal vessels, irrespective of stasis, was a feature of the disease Banti called attention to, and it may have some bearing on this symptom of recurrent bleeding.

Now let us return to this box, not only that I may show you what these accumulations are, but that I may tell you the end-results of the story of our friend from Fincastle. I do so particularly because I want to warn you as well as my junior surgical colleagues here lest there be too great enthusiasm over splenectomies for these obscure diseases.

I am led the more to do so because Mr. B—— has told us that in this patient we have just seen, splenectomy is the proper procedure, but I am not at all sure but that the boy's mother is correct in believing that she has lived as long with her hemolytic jaundice as she would have done if her spleen had been removed. I find that in the hospital records here there have been seven cases of splenectomy for the following conditions: splenic anemia, 1; splenomegaly, 2; pernicious anemia, 2; fever, cause unknown, 1, and chronic splenitis, 1; not a

Water color sketch by August Horne of the esophageal varices with perforation, leading to fatal hemorrhage in the second case.

very large series, and I will show you two recent articles on the subject, one of them from the Mayo Clinic, where possibly the largest experience has been had with these particular operations.

Unless the spleen is very adherent and very large and unless the patient is unduly anemic and in poor health, its removal is not an operation of exceptional magnitude; and unquestionably when we are reaching out for some therapeutic measure in regard to a possible cure of an obscure disease the temptation is strong to remove an organ which evidently participates in the disease, if it is removable, even though it may not be the primary source of the disorder. We must not, however, be misled under the circumstances by mere operative recoveries into the belief that the patient has necessarily been benefited — benefited in the way that Alvin Landers has been by his hernia operation, which you will recognize as having been an urgent and possibly life-saving procedure.

I feel a little conscious-smitten when I find that the case of Mr. C. D. B.—— has gotten into the literature as one of the early recoveries and possible cures of Banti's disease by removal of the spleen — particularly as *two cases*. For here is a much-quoted article by Gaston Torrance, on "Splenectomy in Banti's Disease," reprinted from the *Annals of Surgery* for January, 1908. Thirty-six cases were then collected, of which that of C. D. B.—— was XII, and it states that "he made a good recovery and gained 30 lbs. in weight;" also that "he was reported living and well eight years later, with no return of the hemorrhages." Case XIII of the same series is evidently the same patient and accredited to my then chief, Dr. Halsted. There had been eight recoveries out of the eleven preceding cases, going back to one by Spencer Wells in 1865. These favorable reports — especially when a success is counted twice — unquestionably are what encourage subsequent operations. This is quite proper, and it is natural that we should continue with these measures, but we must not let ourselves be blinded by incomplete reports of these operative recoveries.

Now let us return again to our filing box and see what happened to the patient from Fincastle, Va. Here, in this old rubber band, is a package of cards labeled "Splenic Anemia," with some fifty or sixty references collected in 1900, and you may imagine what the collected literature of the subject must be today. You will find it in the Index Catalogue when you need it.

Here is a bundle of notes on the diseases of the spleen and their surgical treatment, and here are several starts at the writing of a paper on the subject, finally abandoned. One of them begins: "Nebular as they are, these are essentially borderline conditions of medicine and surgery, and consequently of interest to all," and further, that "some day order may come out of chaos and the disorders now classified as

'pseudoleukemia,' of which Banti's disease appears to be a type, may be found to represent a great diversity of conditions." Some of this might have been written today. And here is a postoperative chart by Dr. Follis who was then a fourth-year medical student like some of you here, and he industriously followed this man's blood for two months after the operation, with an almost daily differential count — and you know what this means — though I do not know that we observed anything especially noteworthy except a well-marked poikilocytosis after the operation. And here — a letter from Dr. Osler urging that these cases be written up from a surgical standpoint. And a bundle of reprints on the spleen and its diseases, among them Banti's two papers with a manuscript translation of one of them, made by some one, I've forgotten who. Then a package of some twenty letters from the patient from about as many addresses. For your information as well as entertainment I will quote from some of them, for they are in part amusing and in part tragic. This of March 15, 1900:

Dear Sir men of good business have advised me to write to the Hospital as it is well known there can be no advertisement put out that will represent the Hospital as well as the scares on my body. I can readily see and know and have knowed for some time that I can send many afflicted people there that never will come until they see what has bin don for me. I wrote to Dr. Henry M. Herd on this mail will you see him and pleas have a talk with him and youall can tell me what is the very bes salery they can pay me as I can see some time ago the people I can induce to come it will be a big thing pleas let me hear from you and all about the matter very Respectfully.

So far as I know, Dr. Hurd did not take advantage of this, for two years later, Aug. 12, 1902, we find our patient peddling a patent medicine and attributing his recovery to it.

Dear Friend your letter was received last eavening well I am at home now I got sick. I am trying to introduce A.I.M. will send you one of my circulars *Please* read it and when you cannot stop blood just call on me for I never fail they like me the company as an agent though I worked to hard. Doctor say I Kneed rest and I have liver trouble Kneed some Kind of a mild liver Meadicine all the time A.I.M. is to Strong for me to take very much of it. if I was not one of those Push go ahead Kind of fellows I wouldent be able to do anything at all now you seem to always have so much busines on hand you will never take time to write only a word or too sit up one hour later some night and write a long letter you could do this if you would well when I was operated on I weighed 157 I now weighe near about 140 they say anything that has its spleen removed natural grows thin guess I will dwindle to nothing finaly now write me soon and send me your Picture, &c.

A year later finds him married and on a farm— complaining of

Rheumatism I guess I am subject to it all through my body some of it maybe due to me handling the Pruning Shers my mussles seam to be harder than when I come here hard work has made them hard I guess. When I get up of

morning I spit up some seliva very bloody looking or almost blood itself. I taken some of the Mineral about a yer ago and lots of hard blood Passed from me at Stools for 3 or 4 times just like I used to pass when I had those hemorages etc.

Here I must have lost track of him, for there are some returned letters, and there is a gap of six years till 1909, when this from a new address:

Dear Doctor one week ago today I was taken with a severe hemorage threw up as much as a pint of blood lost over three quarts of blood all together most of it passed through my bowels this time when I use to have those hemorages eleven years ago before I come to the hospital I would vomate as much as a gallon to a gallon and a half the Dr. come to see me the second day the first day he said I must have blood ulcer or cancer of the stomach and that he wanted to go home and read up my case, etc.

A wise doctor, particularly as he said the next day:

I dont think you have blood ulcer or cancer since I have read up on Dr. Oslers work and he did not give. me any medicine at all only told me to take a dose or too of oil and I don so. I can begin to eat a little something again everybody tells me I work to hard, etc.

A good soul, as you will see, but just how much he has benefited by his splenectomy there may be some justifiable doubt.[3] The matter might be argued both ways; and it might be said that otherwise he would certainly by this time have been in the stage of cirrhosis and ascites. Who can tell?

But the last and most important document in this box is a description by W. G. MacCallum, of the pathologic changes in the spleens of these two patients, which well deserves publication even after these twenty years, if for no other reason than to show how little additional knowledge we have at the present day.

Now Gentlemen, I do not mean to imply by what I have told you at this exercise that these are the only books of reference, for there are of course many others equally valuable, in our own and foreign tongues. The main thing is for you to get accustomed to certain sources of information, so that you can pick up a subject in its essential details and know how to follow it to its full elaboration.

Nor do I mean to imply from what I have told you of the keeping of case records or subject records that this is the only way, for each of you must work out a method more or less applicable to his own characteristics of work. The essential thing is to remember that medicine

3. Since this clinic I have again heard from this man (Feb. 13, 1920, twenty-one years since his operation) and he reports another hemorrhage in July of 1918 when he vomited about a quart of blood which he attributes to pitching hay, and he still works too hard and would like a position here because he once worked at an asylum in Osawotomie, Kan., and has "the name of being a fine salesman but he doesn't say it boastingly."

is a rapidly changing subject, that no one can keep pace with all branches of it, that if you are going to succeed you will have to be a student of medicine the rest of your days, that this is the time, if any, to establish good habits of work and to learn how to assemble facts relating to disease as they come to your knowledge, so that they may hereafter be useful to you.

You must remember, too, that just as the physician may be deluded by blind faith in regard to the efficacy of drugs, so may the surgeon be misled by his operations — the capacity for self-deception is strongly developed in all of us. It is well to keep a reasonably skeptical attitude regarding cures, for then you are never vexed when you find you have been in the wrong. You can learn to practice medicine successfully with a very few drugs well used, and will become the better surgeons for conservatism in the use of the scalpel.

To return for a moment to our patient with hemolytic jaundice, whose spleen it is proposed to remove. I see no reason why it should not be done, but at the same time feel some sympathy for his mother's point of view. The risks are not great and, so far as we know, it at least should do no harm, but in the present stage of our ignorance of these disorders, not knowing indeed whether the spleen is the primary seat of the disease, we at least should feel obligated to take every advantage of such an operation to advance our knowledge, by following the case through for a reasonable time before letting it get into medical literature as a presumptive cure. This is a temptation to which the guild of surgeons is particularly prone.

THE PATHOLOGICAL CHANGES IN SPLENIC ANEMIA

BY W. G. MAC CALLUM

Of the pathologic examinations carried out in cases of so-called splenic anemia, the most satisfactory are those of Banti, Harris and Herzog, Sippy, Bovaird and Gaucher. Others are very brief indeed and generally limited to the macroscopic inspection of the organs. The cases described by these authors are, however, not homogeneous in their character — those of Bovaird and Gaucher being apparently quite different from those described by Banti, and later by Sippy and Harris and Herzog. With the types described by Bovaird, we have in the other cases nothing exactly comparable. The enormous widening of the venous channels in the pulp with the proliferation of the endothelial cells is not found by Banti in his case. Banti found merely a diffuse new growth of interstitial connective tissue throughout the pulp marking out the venous channels, and a change which he considers primary in the malpighian bodies leading to their sclerosis. These changes, even when taken together with the other details which Banti brings forward, do not seem sufficiently characteristic from the

anatomic point of view to justify the classification of the condition as a separate disease. Such a classification must rest until an etiologic factor is determined largely on the clinical course of the disease. Nevertheless, the objective anatomic description of the cases before us may furnish a clue in time to the etiologic factor.

From *the first case,* we have for anatomic study only the spleen with a macroscopic observation as to the condition of the liver at the time of operation.

Note of Dr. Flexner on the spleen, Nov. 10, 1898:

Spleen measures 18 by 11.5 by 2.5-4.5 cm. and weighs 730 gm. Its anterior edge is rounded—notch partially obliterated. Inferior anterior half of capsule thickened, white and opaque. In the central portion there are lines of calcareous deposit. The capsule is thickened generally but not uniformly, elevated plaques being scattered over the surface. Old adhesions exist over the inferior and posterior border as far back as the hilum which bound the spleen to the diaphragm. Gastrosplenic omentum is adherent to the anterior edge. Cut surface exhibits a remarkable uniformity—its general color is deep salmon or reddish brown only variegated by very prominent trabeculae. The malpighian bodies cannot be made out at all.

A few noncalcareous thrombi, oval in shape, are found in branches of the splenic veins—one was concentrically striated. The consistence of the spleen is very much increased.

Splenic Artery: There is some thickening of the wall which is practically always present in adults, and a moderate degree of tortuosity. Intima generally is smooth. There are, however, thickened opaque plaques situated at the points of branching at the hilum of the spleen.

Splenic vein is apparently normal. What remains of a lymph gland on the hilum of the spleen is easily made out and perhaps enlarged.

Microscopically, one finds the trabeculae definitely increased in thickness throughout the section; the capsule, however, is not markedly thickened. The malpighian bodies are less numerous than in a normal spleen; many of them are quite normal in appearance, while others are abnormal only in their very small size. These immature nodules surrounding small arteries occur in the pulp at quite a distance from the coarse trabeculae. In a few of the larger and more normal looking bodies, there is the pale central area in which the cells lying on the reticulum have a large vesicular nucleus, contrasting with the more deeply staining nucleus of the smaller lymphoid cells. In many instances, as will be observed again in the next case, the central portion of the nodule is occupied by a dense mass of the small lymphoid cells, the peripheral cells being slightly larger and less closely arranged. No progressive sclerotic process such as Banti described is seen in these malpighian bodies, nor has it been possible to find any fibrous nodules which might have resulted from such sclerosis. The fine reticulum normally supporting the lymphoid cells is perhaps a little coarser than normal. None of the hyaline masses enclosing cells and

fragments of nuclei, such as Banti described, are found here, although it may be mentioned in passing that it is by no means unusual to find such masses in the greatest variety of conditions, and they can therefore hardly be considered in any way characteristic of this disease.

In the red splenic pulp the changes are definite enough to attract immediate attention; but before detailing them it may be well to review briefly the main points in the histology of this tissue as brought out in the recent papers of Weidenreich, Mall, Thoma and others. The question as to whether or not there is an open or closed blood circulation we may leave aside, as it scarcely concerns us here. More important for the comprehension of these changes is the excellent description of Weidenreich of the minute structure of the venules and arterioles, and the intervening tissue which goes to make up the red pulp. The walls of the arterioles present no especial peculiarities if we except the curious sheath which covers the vessels just before their termination in the capillaries. The wider venules into which these capillaries empty, however, have a very remarkable structure. They are of almost uniform width and lie closely plaited together so as to constitute the greater bulk of the tissue. Their walls consist of a basketwork or network of circular and communicating fibrils very much like the markings on a tracheid vessel in the wood of a plant stem, inside of which there is an extremely delicate basement membrane on which the elongated lining endothelial cells are longitudinally arranged. There has been some discussion as to the nature of the circular fibrils. They stain weakly with Weigert's elastic stain, also with the phosphomolybdic hematoxylin of Mallory, and resist for a time pancreatic digestion so that they may be isolated by digesting a section on a slide.

The endothelial cells have a long, narrow cell body; the nucleus, which has one or two indentations, lies in an expansion of the protoplasm in the middle, and is somewhat elevated above the basement membrane so that in cross section of the venule it projects into the lumen. Between these venules there is a supporting reticulum, the fibrils of which anastomose with those forming the network about the venules. Definite connective cells and fibers are present also in small numbers, and there are in the meshes of the network abundant free cells including red blood corpuscles, polymorphonuclear leukocytes and other wandering cells of the type of the lymphoid and plasma cells. In certain conditions, such as acute infection with the pyogenic cocci, we may have an acute splenic tumor, the chief characteristic of which is the great increase in these free cells which form the true pulp cells of the spleen, in contrast with that type of acute splenic tumor which occurs with typhoid fever and in which the hyperemia and endothelial proliferation dominate the picture.

In the case before us, we have, as was mentioned before this digression, changes which are obvious at the first glance. The splenic pulp is markedly poor in cells and the venous channels, ordinarily very thin walled, and to be outlined only with some difficulty on account of their being masked by the great number of cells, are here stouter and extraordinarily distinct. All of the features described above are extremely evident. The intervening tissue, however, has been converted into a fibrillated mass containing only a very few cells of the types usually seen there. Rounded mononuclear cells closely resembling plasma cells are most abundant; polymorphonuclear leukocytes are sometimes seen, and mononuclear and polymorphonuclear eosinophils are quite numerous. There is, as one can determine by suitable stains, a great increase in the connective tissue between the venules. Wavy strands of white fibrous tissue course along here although, as mentioned by various writers, there is no evidence of cell proliferation to give rise to all that new tissue. They lean to the view that the cells of connective tissue nature already present produce more interstitial substance and thus cause the sclerosis of the tissue.

The venules are not distended and do not reach the size ordinarily seen in cases of advanced chronic passive congestion, the condition which perhaps most of all resembles that seen here. They are not even filled with blood in the section, although of course that fact may be due to the draining of the spleen of its blood at the time of the operation. Many mononuclear cells are seen in these venules as well as in the large veins. They may be in large part desquamated endothelial cells, since they are by no means so abundant in the peripheral portions of the section, or in sections in which the fixation of the tissue has been very accurately carried out.

A neighboring lymph gland shows no especial pathologic alterations. There is no deposit of pigment of any sort — no phagocytic cells are to be seen, nor are there any other evidences in the spleen of an active hemolysis. One or two miliary tubercles with beginning necrosis of the center and giant cells are found in the pulp.

In *the second case* the spleen was removed successfully and the death of the patient occurred ten days later from an extensive hemorrhage from a dilated esophageal vein.

The macroscopic examination of the spleen was recorded in the following note:

> Spleen removed by Dr. Cushing. Spleen is much enlarged. Dr. Cushing said that it is much smaller now that blood is expressed than before the operation. It weighs 1,000 gm. and measures 25.5 by 14.5 by 8.5 cm. It is somewhat irregularly lobulated.
>
> The capsule is not much thickened in general, but presents lines of opacity forming a network.

Over the convex surface is an area 11 by 4 cm. where the capsule is much thickened and contains calcified plates. There are a few small nodules of such thickening scattered here and there over surface. The vessels at the hilum are not thrombosed. The arteries are markedly sclerosed. The veins appear normal and rather wide. The main splenic vein measures 2 cm. in circumference; i. e., about 7 mm. in diameter.

The spleen in general is soft and flabby and is not dense and firm as in the case of a spleen of chronic passive congestion. It has rather a pale color. On section the spleen has a similar pale red color. The malpighian bodies are seen with great difficulty. They are apparently diminished in size. The blood vessels are very prominent. The walls are thickened and opaque, gaping open on cut section. The trabeculae are also much increased in relation to the pulp. The pulp is somewhat translucent, and trabeculae can be seen as opaque lines running beneath the cut surface. The spleen though soft is extremely tough, reminding one of very soft rubber. A small portion can be crushed only with difficulty by the fingers. The pulp is thus not friable, and this character together with a slight translucency gives one the impression that there is an increase in the connective tissue throughout. It has nothing of the opaque velvety appearance of acute splenic tumor, and the cut surface is quite smooth and glistening.

Autopsy. MacCallum. Jan. 9, 1900. Autopsy No. 1469.

Anatomic Diagnosis: *Primitive splenomegaly. Operation for removal of spleen. Cirrhosis of liver. Interstitial pancreatitis. Hemorrhage from esophageal varix.*

The body is that of a well nourished man, 165 cm in length. There is a wound in the left hypochondrium 20 cm. in length which extends to the crest of the ileum. It is completely closed by sutures. The peritoneal cavity contains about 100 c.c. of blood-stained fluid.

The thoracic viscera are practically normal except for a slight arteriosclerotic thickening of the aortic valves.

The liver weighs 1,300 gm., and measures 24.5 by 14.5 by 9.5 cm. It is distinctly smaller than normal. The surface is roughened, but not definitely hobnailed. It is yellowish brown in color with a slight greenish tint, and both from the outside and on the cut surface has a translucent appearance. The consistence is firmer and more elastic than normal. The lobules are not very sharply outlined, but interlobular strands of grayish tissue can be made out here and there. The portal vein at its entrance into the liver is occluded by a thrombus.

The peritoneum about the site of the operation is not injected. There is no hemorrhage and no peritonitis, except that the omentum and stomach are delicately adherent to the diaphragm. The diaphragm is somewhat congested, and severed veins are everywhere plugged with dark thrombi. The splenic artery is tortuous in its course over the tail of the pancreas where it is ligated. The splenic vein is wide and accompanies the artery; it is also ligated. Both are occluded by thrombi of which that in the artery is firm and lamellated. The wall of the vein is perhaps slightly thickened. The thrombus in the lumen, which has a central softened portion, extends along the vein into the portal, where it rolls up and occludes the vein at the hilum of the liver. The inferior mesenteric, diaphragmatic and gastric veins and left renal veins are occluded by thrombi. That in the portal vein is, however, limited to the hilum of the liver.

The stomach and duodenum are distended with bloody fluid and clots, the stomach containing over a liter. The gastric mucosa is pale and normal looking. One or two thrombosed submucous veins are seen through the mucosa. In the esophagus at its lower end there are widely dilated submucous veins, most of which seem to be thrombosed. One just beneath the mucosa is apparently the source of the hemorrhage, for there is a small punched out ulcer opening directly into it, as shown in the illustration.

The pancreas was slightly injured at the tip of the tail and there are scattered areas of fat necrosis in the neighborhood.

The kidneys are large, but show no especial pathologic alterations. In the fat about the splenic flexure of the colon there is an accessory spleen about 2 cm. in diameter resembling, on section, the main spleen. The inguinal and femoral glands are enlarged, white and firm.

Bone marrow of the femur is pale purplish red in color and quite firm. The fat is quite masked by the cellular elements.

All the organs are very anemic and the heart's blood thin and watery.

Microscopically, the changes are most marked in the spleen and liver. The bone marrow proves to be exceedingly rich in cells of the types usually found in actively proliferating marrow. Erythroblasts are very numerous indeed. The lymph glands show no characteristic abnormality. Special attention at that time was not directed to the hemolymph glands, and none of them can be found in the preserved material.

The accessory spleen is completely necrotic, its vessels being thrombosed and entirely occluded. What remains of the architecture, however, is enough to show that it had undergone the same changes as the main spleen. The kidneys microscopically are practically normal, except for a very insignificent increase of connective tissue in certain areas. In the pancreas there is a well marked chronic interlobular and intralobular pancreatitis without very extensive degenerative changes in the parenchyma cells. The changes in the liver are very slight as compared with those in the spleen. There is a cirrhosis, that is, there is an increase in the connective tissue in the portal spaces, but this is not an extensive new formation of tissue, such as one sees in alcoholic cirrhosis. The bands of fibrous tissue are narrow and have not the appearance of having been recently formed — they are instead very dense and poor in cells — newly formed bile ducts are almost entirely wanting in them. The liver cells show a good deal of fatty degeneration, and there is great inequality in the size of their nuclei.

The veins in the submucosa of the stomach, especially about the cardiac orifice, are distended with blood.

The sections of the spleen show no definite thickening of the capsule; the trabeculae, however, are much thickened. The alterations of the pulp and malpighian bodies resemble in general those seen in the first case. The malpighian bodies are not numerous. Indeed, as compared with the normal spleen, very few of them are to be found in a

section; but this may, of course, be due to the enormous increase in the bulk of the red splenic pulp which separates them widely. They are in general normal in appearance with the exception of a diffuse thickening of the reticulum. Often there is the frequently described central area with large pale nuclei in many of which mitotic figures are visible — fragments of nuclei and occasionally fine fragments of hyaline material are seen between these cells. None have undergone any extensive sclerosis, and it has not been possible to find one completely converted into a fibrous mass.

The red splenic pulp is greatly increased in amount — there must be a great new formation of vessels, because the increase in the interstitial tissue alone does not seem to be sufficient to account for the enormous enlargement of the spleen. The pulp too consists, as in the preceding case, almost exclusively of closely matted venules whose walls are rather more definite than normal, but which are not dilated to a diameter greater than normal. In the interstices there is a distinct increase in the connective tissue which runs in wavy lines between the venules. Mallory's connective tissue stain brings out a fairly dense network in which the venules lie. In digested and stained preparations, however, the reticulum which becomes isolated as a delicate basketwork does not appear to be very greatly thickened over the normal, and indeed the individual venules are not especially stouter than the normal. Nor in all parts is the distribution of the new connective tissue homogeneous — there are areas in which the venules lie immediately together, while just adjacent to them there are bundles of connective tissue fibers separating the blood channels. Apparently, therefore, the change in the bulk and consistence of the red splenic pulp is due to a great increase in the venules and their closer packing together on account of the lack of abundant pulp cells together with a definite formation of new connective tissue throughout.

As in the preceding case the cells in the interstices are very few in number. Those which are left are of the lymphoid and plasma cell type with some polymorphonuclear leukocytes and relatively abundant mononuclear and polymorphonuclear eosinophils, some of which are so large as to form very striking objects. Large giant cells also sometimes occur in these spaces; they are irregular in outline and contain several nuclei clumped together in the middle.

Here, as in the lymph glands, the tests for iron holding pigment were negative.

Finally, we have the spleen from the case reported by Dr. Osler[4] as Case XVI. This spleen was also enormously enlarged, measuring 24 by 14 by 7 cm. The surface is somewhat roughened by shreds of

4. Osler, William: Anemia Splenica (second paper), Tr. A. Am. Phys., 1902.

old adhesions, but the capsule was not particularly thickened. On section, it has the same semitranslucent grayish lilac or grayish red color as in the preceding case; the cut surface is quite smooth and sinks slightly into a concavity. The malpighian bodies are not at all prominent, but the trabeculae and vessels are quite conspicuous. The spleen has the elastic rubbery consistence described for the others. The blood vessels at the hilum are somewhat dilated, but show no other abnormalities.

Microscopically, the trabeculae are very inconspicuous and indefinitely outlined; they seem to merge into the surrounding tissue. There are a few small hemorrhages in the splenic substance beneath the capsule as well as elsewhere scattered in the pulp; probably these were due to the handling of the spleen during the operation.

The splenic pulp is pale and anemic, and there are strands of pale staining connective tissue running throughout it and separating quite widely the venules. The new growth of connective tissue is far more marked here than in the other cases, and with Mallory's stain gives a blue meshwork of coarse fibers with very narrow meshes. The venules, indeed, seem narrower than normal. The basketwork of the reticulum fibrils in the spleen about the venules seems to be denser than normal; it is very intimately associated with the connective tissue of new growth.

The connective tissue between the channels is exceedingly poor in cells; it stains pale pink and has a finely fibrillated appearance; with Mallory's stain it takes a deep blue and the fibrillation is more evident. Definite connective tissue cells are relatively few in number, and no evidence of mitosis has been made out. Free cells of the lymphoid and plasma cell type occur, however, sparingly distributed, and there are quite numerous mononuclear and polymorphonuclear eosinophils. The last are so abundant as to be quite a striking feature in the section, occurring also in the blood channels.

The malpighian bodies are few in number in a section, but are practically normal. The central cells are generally the smaller and more closely crowded together, while the peripheral are larger and more loosely arranged; large epithelioid cells occur scattered among them. There is no evidence of any primary sclerosis of this part of the tissue. They rarely show any centers of active cell proliferation, and areas of cell degeneration and hyaline necrosis are quite as rare.

In these three cases, therefore, we have practically identical conditions in the spleen. In all, the malpighian bodies show practically no pathologic changes of any significance. They are scattered by the changes in the pulp and often small, but no more characteristic changes occur. In the pulp, there is apparently a great increase in the number of the venules which are not dilated, but from the loss of cellular tissue

between them have come to compose the greater part of the tissue. The basketwork of fibrils surrounding these venules seems not to be much altered, but there is a definite new growth of connective tissue between the venules. The endophlebitis described by Banti has not been made out in these cases. There is no evidence of great hemolysis in the spleen or elsewhere in the body, if we except the regenerative activity of the bone marrow. In one of these cases the man is apparently well two years after the splenectomy; in one there is slight cirrhosis of the liver, while in the third we have no evidence as to the condition of the liver. Speculation as to the nature of the process will probably lead to no definite result. Certainly the condition is not such as is characteristic of the ordinary chronic passive congestion; there are no extravasations of blood with hematoidin formation, no such widening of the venules, and withal a far greater new growth of connective tissue than is ordinarily found in the spleen of chronic passive congestion. There can be no question of malarial infection as an etiologic factor, for there is nothing in the history to indicate this, and there is none of the characteristic malarial pigmentation. It does not seem unreasonable to suppose that some toxin perhaps with a mild hemolytic action may act primarily to produce an enlargement and induration of the spleen and later a cirrhosis of the liver.

DIAPHRAGMATIC HERNIA

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Since the general introduction of roentgen-ray examination of the stomach and intestine after the introduction of barium solution, a great deal of study has been devoted to the subject of diaphragmatic hernia. Many of the cases that before the introduction of the roentgen ray and barium studies could not be diagnosed can now be clearly seen, and definite and accurate diagnoses can be made. This newer method of examination has shown that diaphragmatic hernias are much more common than was formerly believed to be the case. In the days before roentgen-ray examination I was seldom able in my own work to make a definite diagnosis of diaphragmatic hernia. I have recently been able to study with my medical colleagues four of these patients on whom we have subsequently operated. It is my intention to report this clinical experience.

CLASSIFICATION OF DIAPHRAGMATIC HERNIA

Before taking up the details of these cases, however, I should like to discuss briefly the subject of diaphragmatic hernia in general. The cases which we find reported in the literature under this general term can, as a matter of fact, be classified under three heads: first, congenital hernias of the diaphragm; second, acquired hernia in the same sense that the ordinary inguinal hernia of the adult is called an acquired lesion; third, traumatisms of the diaphragm, either from stab wounds, gunshot wounds or subcutaneous ruptures in which the opening in the diaphragm permits of the passage of the intestinal contents into the thoracic cavity. When these cases go on to recovery without any operation and leave a resultant traumatic hernia, they may fairly be classified under the general term of diaphragmatic hernia. On the whole, however, injuries of the diaphragm leading to the escape of the abdominal contents into the thoracic cavity are better classified as gross traumatisms of the diaphragm without including them under the general title of diaphragmatic hernia.

Congenital hernias of the diaphragm occur at several points, one presents itself as a weak point in the diaphragm at the junction of the ensiform process and the costal cartilages. Here a triangular area not covered by muscle is found fairly constantly, and sometimes it is weak enough to permit the development of a hernia, with some of the abdominal contents escaping into the thoracic cavity. A second weak point is found between the

psoas muscle and the ribs, posteriorly. Other congenitally weak points in the diaphragm are the esophageal opening and the openings for the venae azygos and the phrenic nerves. At any of these points and at other portions of the diaphragm, congenital defects may exist which permit of a diaphragmatic hernia. There are cases reported in which there is an entire absence of the diaphragm congenitally.

Not infrequently these cases of congenital diaphragmatic hernia produce few if any symptoms, and a number of cases have been found postmortem in which the history of the individual case gave no evidence that the condition produced any distress or interfered with ordinary functions. Again, it is quite possible for the individual to continue for years in comparatively good health with a congenital diaphragmatic hernia, and then suddenly a strangulation occurs, producing a picture of intestinal obstruction, which, of course, would be very difficult to diagnose and which would then be found either at operation or postmortem.

In the congenital type without any symptoms, in which the condition is discovered accidentally in making a gastro-intestinal examination of the patient with the roentgen ray and barium, the question of the indications for surgical interference would be relative and not positive, and one would want to study such cases with a great deal of care and determine absolutely that the condition was giving rise to symptoms or presented a sufficient menace before undertaking any operation for its correction.

The literature of injuries of the diaphragm from stab and gunshot wounds comes in large part from the Latin countries, where the knife is a more favorite weapon than it is here in America or in Great Britain or Germany, although we in this country have had a fair number of these cases reported from gunshot wounds, stab wounds and contusions. During the World War, a large number of these cases occurred from high explosives and gunshot wounds. A considerable number of these cases were associated, in addition to injury of the diaphragm, with more or less extensive lesions of the contents of the abdominal and thoracic cavities, and often, of course, with other injuries which overshadowed the diaphragmatic injury. In cases of stab wounds of the chest with injury of the diaphragm and resultant hernia, experience has shown the wisdom of adopting the transthoracic route for exploration and repair. In cases in which the injury is primarily of the abdomen with great probability of serious injury to the abdominal viscera, abdominal exploration should be made to determine the condition of the abdominal contents, the question of perforation of the stomach or intestine, hemorrhage, etc. If it is not found, or in the event that it is found and repaired, an attempt should then be made to repair the injury of the diaphragm

through the transabdominal route. If this is not successful, a transthoracic incision should be made, and the incision closed in that way. The experience of operating on these diaphragmatic injuries by the transthoracic route, opening the pleural cavity and repairing the diaphragm, has shown that it is usually possible, that the production of a temporary pneumothorax is not, as a rule, a serious matter, and that the operation can be performed without intratracheal anesthesia or the pressure cabinet. When infection does not occur, the immediate closure of the wound is followed by a rapid absorption of the air in the chest, and without other complications, the recovery of the patient.

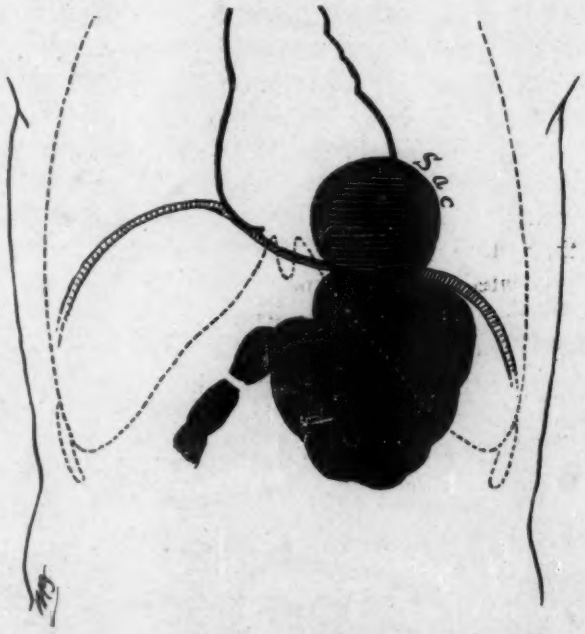

Fig. 1.—Outline of roentgenograms showing hernial sac above esophagus.

ACQUIRED HERNIA OF THE DIAPHRAGM

The particular type of hernia which I desire to discuss is what I believe should properly be classed as an acquired hernia of the diaphragm. I would compare this to the acquired inguinal hernia that we ordinarily see. My experience has been limited to four recent cases of this type, but it leads me to believe that these acquired hernias of the diaphragm occur always at the esophageal opening just as inguinal hernias occur at the external abdominal ring. The parallel between these esophageal diaphragmatic hernias and inguinal hernias passing along the spermatic cord or the round ligament is

very close. We have in both instances a weak point, this particular portion of the wall being weakened by the passage through it of some structure, in one instance the cord and in the other instance the esophagus. At this weak point, probably from gradually increased intra-abdominal pressure, the peritoneal sac first makes its way and then some of the abdominal contents are forced into this sac. In the case of diaphragmatic hernia, we almost never have a hernia on the right side of the diaphragm on account of the position of the liver, and the contents that pass through at the esophageal opening are, therefore, the contents of the left side of the abdominal cavity in this order: first and most commonly, the stomach, then the great omentum, then the transverse colon, and lastly, in some rare cases, the small intestine. Like inguinal hernias, these hernias are in part reducible and in part irreducible because of the formation of adhesions.

The clinical picture of diaphragmatic hernia of the stomach is by no means a constant one. The picture that I have seen has been, first, stomach distress, sometimes daily and sometimes coming on at longer intervals; the daily stomach distress is sometimes associated with pain coming on some time after the ingestion of food, simulating sometwhat the picture of ulcer, sometimes that of gallstone disease and sometimes associated with vomiting, simulating the picture of pyloric obstruction. Occasionally, these patients have pain only at long intervals and then apparently when they have overeaten or eaten something that has disagreed with them, perhaps forming a good deal of gas. In one of our cases the pain was particularly excruciating and came on at such irregular intervals as to suggest strongly the possibility of gallstone colic attacks.

The clinical picture of the cases in which the colon is involved may be suggestive of a beginning obstruction from carcinoma, a partial intestinal obstruction relieved by cathartics and enemas, with a disappearance of the symptoms and then a recurrence after an interval of days or weeks. Of course, the picture of strangulation of the small intestine or of the colon gives the picture of intestinal obstruction from an unknown cause unless definite evidence of a diaphragmatic hernia can be obtained with the roentgen ray. Of course, in all these cases, a very careful history should be taken and a very careful analysis made of the evidence obtained. After all, a definite diagnosis must rest on fluoroscopic examination and the taking of roentgenograms. The evidence is very gratifying. Fluoroscopic examination in one of these cases with a barium meal introduced into the stomach showed a filling of the stomach and then a gradual filling of the pouch above the diaphragm, which could be easily seen and outlined (Fig. 1). When the colon

is involved, the best evidence is obtained by the introduction of a barium solution into the colon followed by fluoroscopic examination and the taking of roentgenograms. In the few cases in which the small intestine is involved, the evidence of involvement of the small intestine is confusing. Sometimes, however, this fact can be definitely

Fig. 2.—S-shaped incision on left side.

determined from the roentgenograms, especially roentgenograms or fluoroscopic examination made over different periods of time after the introduction of the barium solution.

SURGICAL THERAPY

In cases in which a definite diagnosis of diaphragmatic hernia can be made and the patient presents symptoms which can be ascribed to this lesion, unless there is some very strong contraindication, an

attempt should be made to cure the patient by operation. We have worked out a technic which has seemed quite satisfactory. The first essential is a wide exposure which will enable one to reach the esophageal opening and to reduce the hernia and close the opening so as to prevent recurrence of the condition. After a careful study, I have come to the conclusion that the large S-shaped incision made on the left side, such as we have for a number of years employed in our splenectomies (Fig. 2), answers the purpose better than any other. The incision should be carried well down, either to, or an inch or an inch and a half below, the umbilicus, and carried through

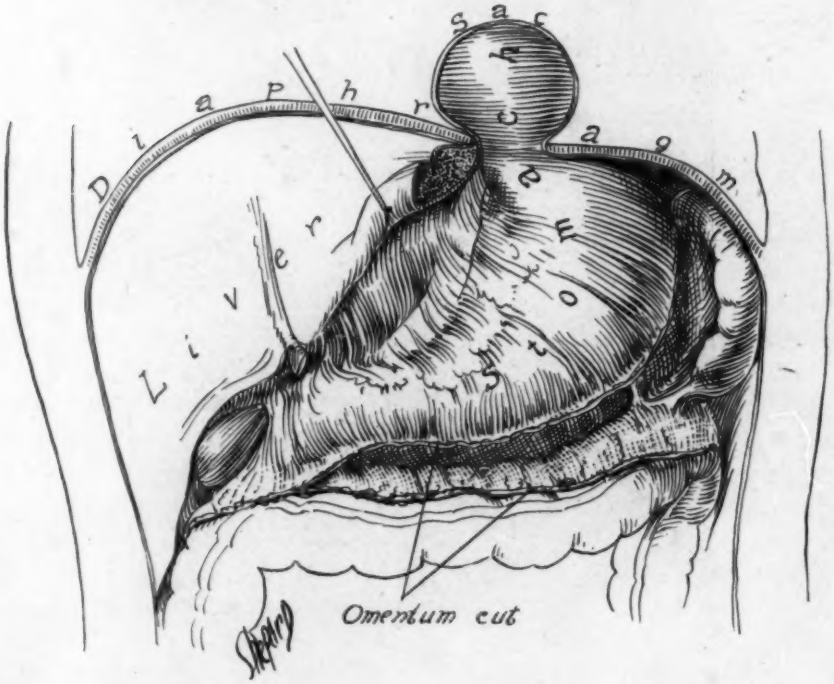

Fig. 3.—Stomach in diaphragmatic hernia.

the rectus muscle at the lower limb of the incision. Large abdominal pads are then used to hold back the abdominal contents. One wants complete relaxation under a general anesthetic. I have operated with these patients in the recumbent position. I have never tried using the reversed Trendelenburg with the idea of allowing the abdominal contents to pass to the lower part of the abdomen, and yet I believe this might be very properly considered. Holding the abdominal incision widely apart with large retractors, the hand is passed into the abdominal cavity in front of the stomach to the

esophageal opening and the contents of the diaphragmatic hernia gently pulled down into the abdominal cavity, whether it be the stomach, intestine or omentum. When the hernia is reducible this is very easily done, and one sees at once the exact condition at the esophageal opening through which the abdominal contents have passed into the thoracic cavity (Figs. 3, 4 and 5). The closure of the opening is comparatively simple, either with good sized catgut or with silk or linen, I believe preferably catgut. With a large full curved noncutting needle the pillars of the diaphragm are firmly grasped and the hernial opening is closed (Fig. 6).

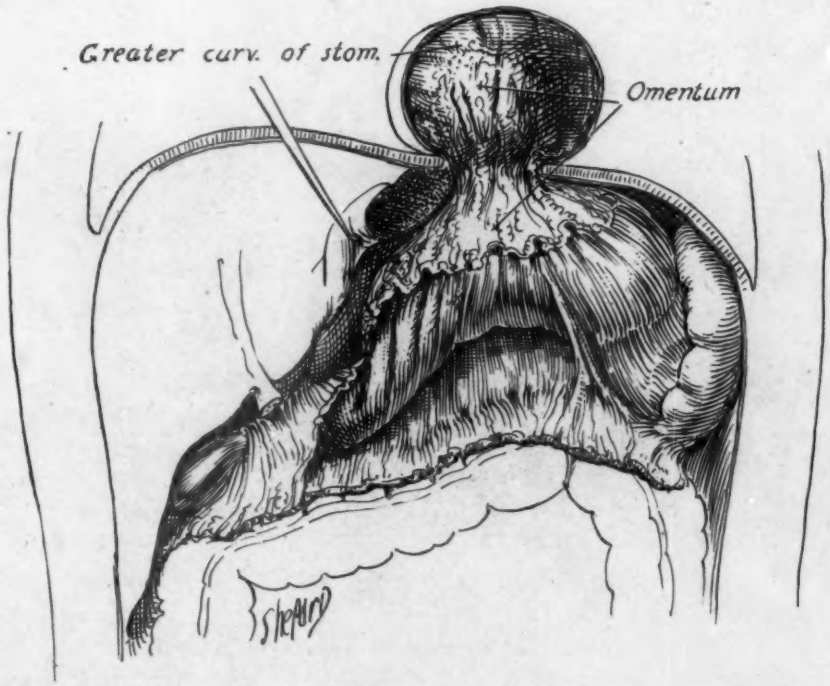

Fig. 4.—Hernia of omentum and greater curvature of stomach.

I believe it is well for the surgeon to study the anatomy of the diaphragm carefully before performing this operation, as this will give him courage to take a large bite of the muscular pillar in each suture. One can employ either a continuous suture or interrupted sutures. Possibly, on the whole, interrupted sutures are to be preferred. With three, four, or in some cases, five or more sutures, the opening is closed down snugly around the esophagus. This of itself will prevent an immediate recurrence of the hernia and the

passage of the contents into the thorax. In order, however, to add additional security, we have in most of our cases sewed the stomach to the diaphragm or to the parietal peritoneum (Figs. 7 and 8). In some cases, it is comparatively easy to sew it to the diaphragm for several inches. In our last case, we found this was difficult, and we found that it was necessary to sew the anterior part of the stomach, which had a great tendency to pass back into the thorax, to the parietal peritoneum.

The after-treatment is simple. Physiologic sodium chlorid solution is given by rectum for twenty-four or forty-eight hours, and then

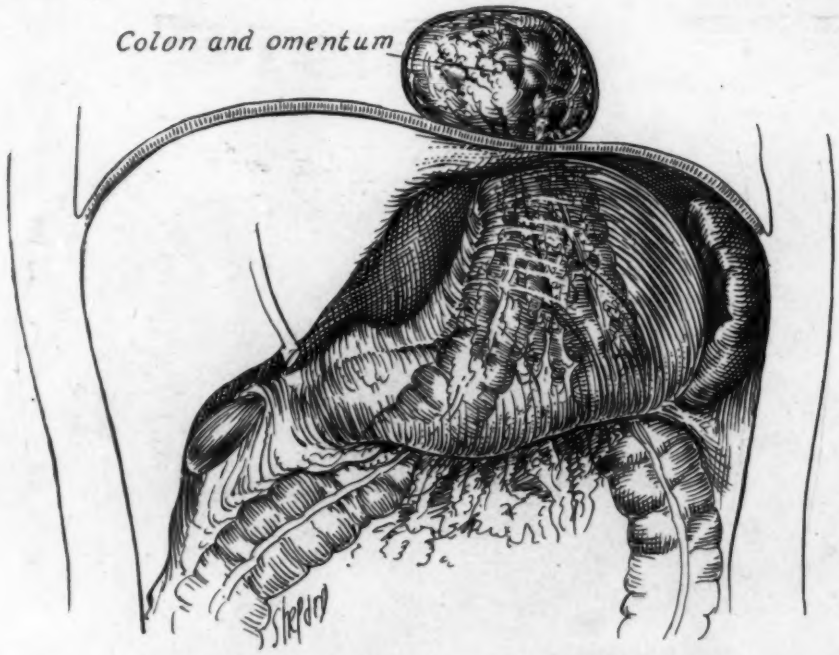

Fig. 5.—Colon and omentum in diaphragmatic hernia.

the patient is fed very much after the ordinary gastro-enterostomy or pyloric resection—small amounts of food every hour. On account of the large size of the incision, we have lately been using three or four button sutures in addition to the ordinary closure.

The results have been admirable, three of the patients making complete recoveries. One patient died; this outcome, however, was due not to the technic, but to the pathologic condition. This was a very interesting case in which the diagnosis of diaphragmatic hernia, part of the stomach passing into the thoracic cavity, was definitely established by roentgenograms. The woman was quite distended, and we believed that the distention was due to the hernia. At operation,

we readily reduced the stomach, closed the opening and performed what we thought was a very satisfactory operation, expecting the patient to proceed to a good operative recovery. Unfortunately, however, she became very greatly distended, and in spite of medication and washing out the stomach, this continued, and she died shortly after the operation. We were able to obtain a postmortem examination, which revealed a small circular carcinoma at the splenic flexure, which was probably an important etiologic factor in the production of the diaphragmatic hernia and the condition which had gradually produced distention of the abdominal contents and increased intra-abdominal tension with resultant diaphragmatic hernia. I present a brief summary of these four cases.

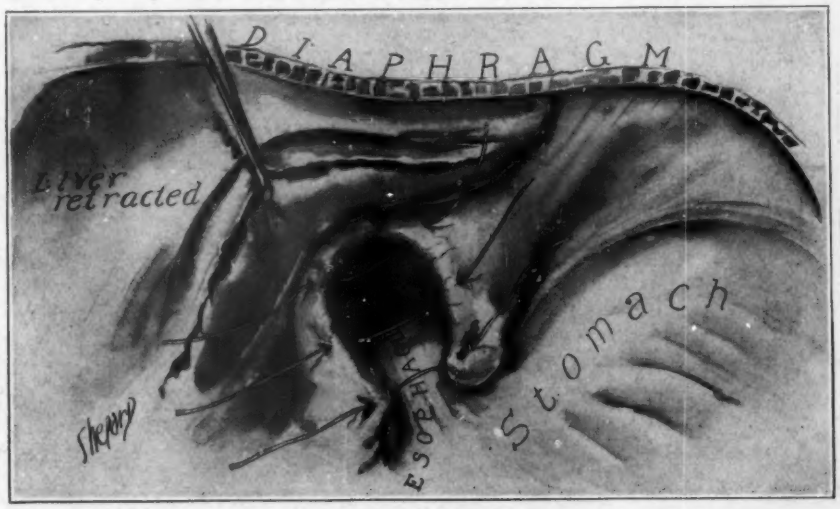

Fig. 6.—Sutures placed for closure of hernial opening.

REPORT OF CASES

Case 1.—*History.*—Mrs. A. W., aged 57, on the service of Dr. Sippy, who complained of pain in the epigastrium, a dull ache over the gallbladder region, cramplike pains in the abdomen, loss of weight and constipation, dated the onset back three years, at which time she had had a very severe attack of "heartburn" coming about one and one-half hours after breakfast. She belched up sour material but did not vomit. The attack lasted until noon. From six to eight months later, the patient began having severe attacks of pain in the epigastrium coming on at the time of eating, or immediately afterward. They were of short duration (from ten to twenty minutes), but gradually increased in severity and frequency so that lately they had caused her to double up. At times during an attack, there was a cramping sensation. The attack seemed worse when she was eating soups or soft things which could be taken quickly. She had never been tender to touch or pressure even during an attack, but had noticed that the jolting of walking increased the pain.

Belching gave the quickest relief, and she was often able to finish her meal after an attack. Besides the attacks which came on during meals, she had had frequent short attacks of sharp, cramplike pain beginning in the right hypochondrium and extending to the umbilicus. These attacks came on when the patient stooped over, and were severe enough at times to require an opiate, but they lasted only a short time. The patient had lost about 25 pounds in weight during the past six months. The maximum weight was 208 pounds; now it was 173 pounds.

Examination.—The roentgen ray revealed the fact that fluid food passed into the esophagus, apparently part way into the stomach and thence into a pouch above the diaphragm. After this pouch had been filled, the rest of the small stomach pouch below this was filled up by the bismuth meal. Possibility of a diverticulum from the lower esophagus had been considered.

Diaphragmatic hernia was diagnosed.

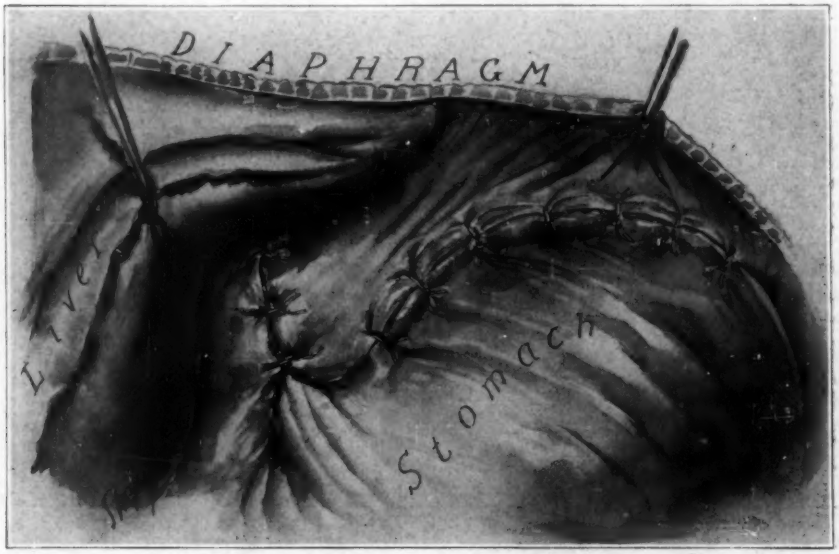

Fig. 7.—Hernial opening closed; stomach sutured to diaphragm.

Operation and Result.—Under ether anesthesia, a large S-shaped incision was made through the left rectus. A large part of the stomach and some omentum were found in a hernia of the diaphragm at the esophageal opening. These viscera were pulled down into the peritoneal cavity and the opening in the diaphragm closed by four Pagenstecher linen sutures, the part of the stomach reduced from the esophageal opening was sutured to the diaphragm and the anterior part of the stomach was sutured to the parietal peritoneum; the wound was closed and sealed. The wound healed in good condition and the patient left the hospital fifteen days later. A roentgen-ray examination after operation revealed the stomach normal and entirely below the diaphragm.

Case 2.—*History.*—Mrs. E. L., aged 55, with a blood pressure of 132 systolic and 94 diastolic, was admitted to the Washington Boulevard Hospital, service of Dr. Sippy, complaining of pain in the abdomen, vomiting, difficulty in

swallowing, weakness, loss of weight and constipation. The present illness had begun suddenly ten weeks before with sharp pain in the abdomen just above the umbilicus associated with vomiting, jaundice and a general feeling of depression. At onset, the pain was not severe except when the patient was

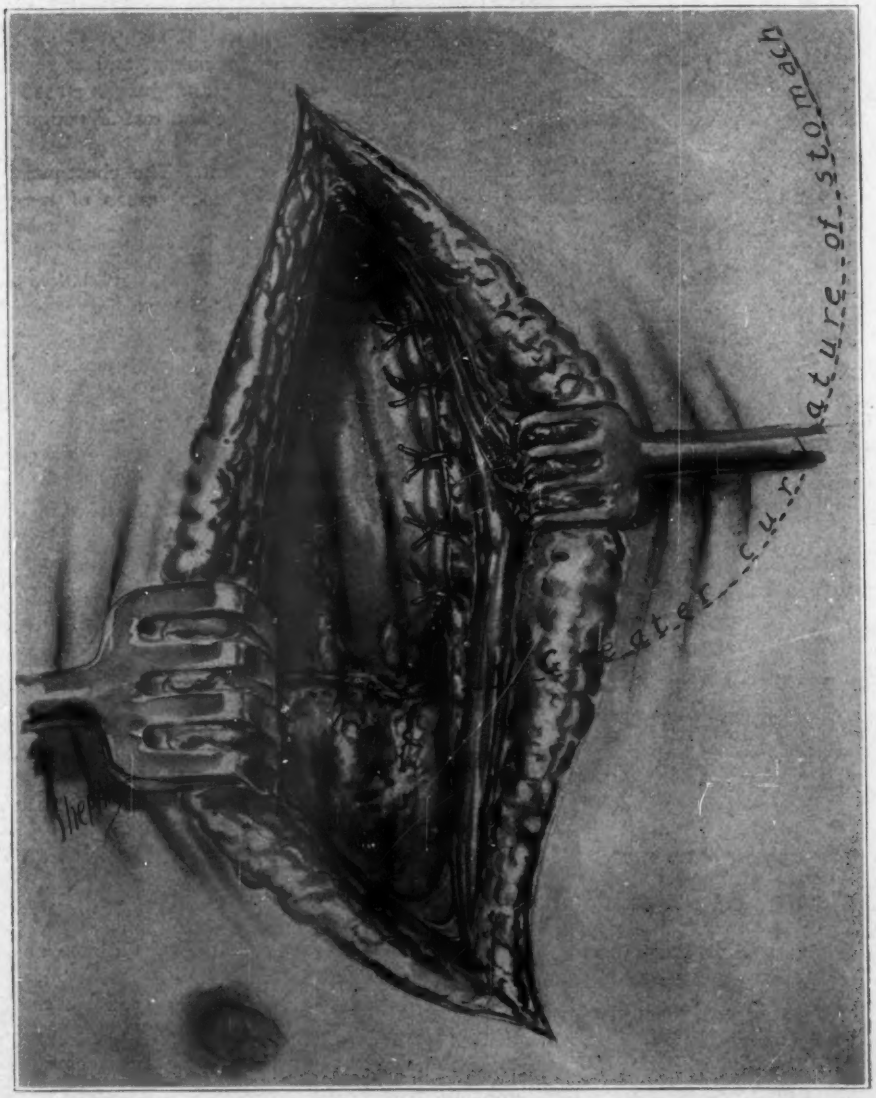

Fig. 8.—Stomach sutured to abdominal wall.

up and about or after the ingestion of food. Six weeks before, the condition had grown gradually worse, and the patient had been forced to remain in bed. The pain and vomiting had markedly increased and had been very severe, at times independent of the ingestion of food. The pain was sharp, cramplike

in character, extended usually across the abdomen just above the umbilicus, and always preceded attacks of vomiting. The right side had been relatively free from pain. Difficulty in swallowing solid foods had begun six weeks before. The food seemed to stick just above the stomach and caused the patient to vomit immediately. There was no difficulty in drinking small amounts of liquid at a time. The patient had always been constipated and had been taking cathartics about twice a week for several years. For the last six weeks, she had been unable to obtain a bowel movement without an enema, and a very slight movement with one. She also had noticed rumbling and gurgling associated with cramps in the abdomen several times a day. She had lost 57 pounds in weight during the last three months.

Physical Examination.—Pyorrhea alveolaris was present. The chest was negative. The abdomen was pendulous and flabby. No local areas of ten-

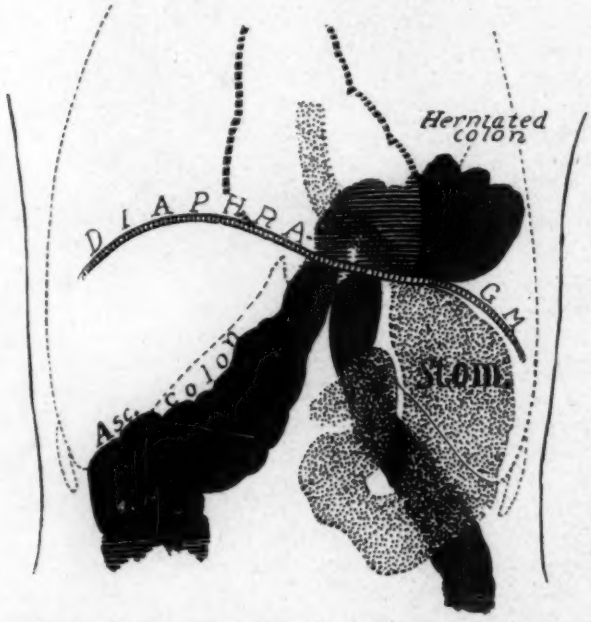

Fig. 9.—Transverse colon in diaphragmatic hernia.

derness and no tumor masses were palpated. Three attempts to pass a stomach tube were unsuccessful. Obstruction was encountered each time at a distance of 15½ inches from the incisor teeth. Attempts to swallow a string were unsuccessful on account of vomiting.

Fluoroscopic Examination.—As barium was swallowed, it was seen accumulating in the apparent position of the lower end of the esophagus. The stomach was shaped like an inverted V, with little or no respiratory mobility on the right side and accurate mobility on left. There was a deep notch in the fundus, and the lower border of this notch was continuous with the curve of the left side of the diaphragm. On deep inspiration, this notch became wider and the projection of the other shadow above the diaphragm became more distinct. This shadow was apparently continuous with the stomach shadow. When the patient was placed on the right side, the shadow, projecting above the dia-

phragm, was continuous with the stomach shadow below the diaphragm; it was not continuous with the esophagus, the esophagus passing behind this shadow. The patient was transferred to the Presbyterian Hospital, still vomiting, where she was given physiologic sodium chlorid retention enemas.

Operation.—Under ether anesthesia, a large S-shaped incision was made. About one half of the stomach was found to be herniated through a small opening of the diaphragm close to the esophagus. The stomach was pulled down, the hernia opening closed and the stomach sutured with catgut so as to cover the hernial opening and prevent the return of the stomach. The incision was closed without drainage. The patient died during the night of postoperative shock.

Necropsy Findings (Dr. Hirsch).—These were: papillary carcinoma of the splenic flexure of the colon; complete occlusion of the bowel; marked distention and hypertrophy of the proximal portion of the colon and of the ileum and jejunum; extensive submucous hemorrhages in the large and small bowel; a large amount of feces proximal to, and absence of feces distal to, the carcinoma of the colon; hernial sac above the diaphragm to the left of the esophagus; moderate fatty changes in the liver; arteriosclerotic myocardium, and scarring of the kidneys.

Case 3.—*History.*—Mrs. L. O'C., aged 41, first entered the service of Dr. Sippy, complaining of vomiting, constipation, loss of weight and strength. Five years before, the patient had begun to have recurring attacks of "heartburn" coming on two to three hours after meals and associated with belching of sour material; coarse foods, vegetables and fruits made it worse. There were periods of several weeks' duration when she was entirely free from distress. During the last two years, the patient had been vomiting, at first only once a week, lately three or four times a week. Usually she vomited two to three hours after meals, sometimes at 1 or 2 a. m. Quarts of material were vomited. At one time, she vomited asparagus she had eaten seventeen hours before. She never vomited blood or "coffee-ground" material. There was no abdominal tenderness. She had lost 30 pounds in six months, having weighed 195 originally. She had used an enema for practically every bowel movement during the last two years.

Examination.—The heart and lungs were negative. There was no abdominal tenderness. The stomach, distended with sodium bicarbonate, showed visible peristalsis.

Fluoroscopic Examination.—This examination, made July 12, 1916, revealed small retention, a large stomach and very vigorous peristalsis, as many as three waves at one time. The antrum was closed off in all directions, uniformly. Occasionally, a small stream of barium could be seen passing through the duodenum. There was no duodenal cap.

Diagnosis and Treatment.—Following a diagnosis of duodenal ulcer, the patient was put on "Sippy" management and left the hospital five weeks later, with the condition improved. She followed directions carefully at home and was all right during the first two or three months, but when she changed to two-hour intervals between feedings, she began to notice nausea and a tendency to "fill up." She aspirated herself several times a day, obtaining from 1 to 4 pints of thin, watery liquid at a time. The patient reentered the hospital six months after dismissal.

Fluoroscopic Examination.—The colon was found behind the stomach and passed through the esophageal opening in the diaphragm. The colon lifted up the outlet of the stomach and portions of the duodenum adjacent to the stomach. Because the duodenum was fixed, malposition and traction on the duodenum probably caused the obstruction. Air could be seen in the colon above the diaphragm. Dr. B. W. Sippy stated that there were "no adequate physical findings on auscultation and percussion to indicate anything abnormal." When the patient was questioned after the fluoroscopic examination, it was found that four or five years before she had fallen down the entire length of stairs, feet first, and had struck on her back. She had had some heartburn before the accident and more after it. She fainted. There had been no vomiting before the accident, but there had been some vomiting at intervals since the accident. Vomiting spells were followed by marked epigastric tenderness so that the patient could not wear a corset.

Operation.—Under ether anesthesia, a large S-shaped incision was made on left side. When the peritoneum was opened the stomach appeared in the wound. The great omentum and transverse colon were found to be herniated into the left thoracic cavity through a diaphragmatic opening the size of a fist. The opening was around the esophageal hiatus. The omentum and colon were pulled back, and the diaphragmatic sac was closed with continuous catgut sutures. The tear in the omentum was closed with catgut. The incision was closed without drainage and the patient left the hospital in sixteen days, entirely recovered.

Case 4.—*History.*—Mr. R. C. D., aged 49, a freight handler, entered the Presbyterian Hospital, on the service of Dr. Sippy, complaining of distress and cramplike pain in the abdomen, tenderness in the epigastrium, nausea and vomiting, constipation, catharsis and pain in the left shoulder. Three years before, the patient had begun to experience distress and soreness in the left side of the abdomen, which came on shortly after eating. He belched considerably. There were periods from a few days to a week when he would feel all right. He also began having great difficulty with the bowels, he had to take a cathartic pill every night. The stools would usually be formed, but sometimes they were mushy or watery. During the last year he had used a cathartic pill and salines. The distress was located chiefly in the left side of the abdomen and epigastrium, and not in the right side at all. It was of a burning character and at times became so severe that the patient could not lie down. It was usually steady, but might be cramplike. In the chest, there was a feeling of fulness under the left ribs and sternum. Attacks of this pain lasted from two to five hours. There was no difficulty in swallowing. During the last year he had had pain in the left shoulder following the severe abdominal pain. Vomiting always gave relief from the epigastric and subscapular pain.

Examination.—This was negative except that there was tenderness across the epigastrium. Respiratory mobility of the lower left lung border posteriorly, was not so good as on the right side, and the breath tones were muffled over the left anterior border.

The stomach was distended with soda and tartaric acid. Some pain was produced a few seconds after inflation. Coincident with the pain, marked rumbling and gurgling sounds were heard just below the left nipple by stethoscope. What appeared to be a great distention and stomach tympany could

be made out as high as the nipple in the midaxillary line, and there was obliteration of normal splenic dulness. The lower border of the stomach could not be definitely made out. No visible peristaltic waves were seen.

Fluoroscopic Examination.—When barium was drunk, the shadow appeared on the left side of the chest, obscuring the heart shadow. The heart was displaced somewhat to the right. When the patient stood to complete the filling, the cardiac orifice was seen below the major part of the stomach as shown by the shadow of barium and the air space above. The colon was filled, with no evidence of obstruction. The transverse colon did not pass through the hernial opening in the diaphragm.

Operation and Result.—Under ether anesthesia, a left side S-shaped incision was made, exposing the stomach. The greater curvature portion of the fundus and antrum with its omentum was found in a peritoneal sac extending through the diaphragm into the mediastinum, the opening being just to the left of the hiatus esophagus. The stomach was delivered from its sac. Adherent omentum was separated. After invaginating the peritoneal sac, catgut sutures were inserted to obliterate the sac and hole. Then the fundus of the stomach was sewed by its greater curvature to the parietal peritoneum. The herniated stomach was rough and in places scarred by fibrous tissue. Two cigaret drains were inserted, but were removed in forty-eight hours. The wound healed by first intention and the patient left the hospital in twenty days cured, as indicated by subsequent fluoroscopic examination.

ESOPHAGEAL DIVERTICULA

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ROCHESTER, MINN.

Although diverticulum of the esophagus occurs more often than we are led to believe from the number of cases reported, it is a comparatively rare condition. Operations on nearly 200 patients with esophageal diverticula, including those in our series, have been reported. Diverticula which do not produce symptoms apparently may occur at almost any point in the esophagus and may be caused by an increase in the intra-esophageal pressure or, more likely, by some tractive force from the outside. Such irregular and small diverticula are often reported in necropsy examinations, but seldom make themselves known during life.

The two common types of esophageal diverticula are the pressure and the traction diverticula. The traction diverticulum commonly occurs in the thoracic part of the esophagus, while the pressure diverticulum is nearly always formed in the cervical region. The traction diverticula are so called because many of them are formed demonstrably by the pulling out of the walls of the esophagus by some inflammatory adhesion. Most often the adhesions have been shown to have resulted from a cicatrix from the suppuration of a lymph node. The traction diverticula are usually multiple and seldom attain an appreciable size or produce symptoms. The apex of the pouch is usually higher than its point of entrance into the esophagus, and, therefore, no opportunity is afforded for food to accumulate, nor is there a tendency for the sac to increase in size. Occasionally, food particles lodge in the pouch, the sac enlarges, due to the pressure from the inside, and in this manner the traction diverticulum is converted into a traction-pressure diverticulum. It is estimated that this conversion takes place in about 7 per cent. of traction diverticula. We have seen two cases of traction-pressure diverticula of the esophagus. At least the patients had good sized diverticular sacs at the lower end of the esophagus. In a previous paper,[1] I reported one of these cases. In both there were symptoms which might be due to diverticula. In the second case, the diverticulum was associated with cardiospasm; this patient was completely relieved by dilating the cardia.

It has not been demonstrated whether a diverticulum in the thoracic part of the esophagus is a true diverticulum in which the sac is com-

1. Judd, E. S.: Esophageal Diverticula, Surg., Gynec. & Obst. **27**:135 (Aug.) 1918.

posed of all coats of the esophagus, or whether it is really a hernia of the mucosa and submucosa through a separation in the musculature. Undoubtedly, the traction diverticulum includes all the layers of the esophagus. Attention has been called to an area in the thoracic esophagus, however, in which the support outside the esophagus is lacking. This is the area in which diverticula are frequently seen (Brosch [2] and LeCount [3]). It is possible that the sac in these cases is formed as a hernia of the mucosa and submucosa as is the case in the pharyngo-esophageal diverticulum, and a pressure diverticulum thus occurs in the lower part of the esophagus.

Zenker and Ziemssen,[4] in 1877, first described the pressure diverticulum, and since that time it has been known as the Zenker pharyngo-esophageal diverticulum. This diverticulum always occurs at the same point in the wall of the esophagus, known as the pharyngo-esophageal dimple, which is just behind the cricoid cartilage on the posterior wall at its juncture with the pharynx (Fig. 1). This weakness in the wall of the esophagus is the result of the arrangement of the musculature of the lower end of the pharynx and the upper end of the esophagus. During the act of swallowing, considerable pressure may be exerted from the inner part of the esophagus, and it is quite natural that the inner coats might be gradually forced through a chink in the outer coats and in this way form a simple pouch. The pouch would tend to increase in size each time the intra-esophageal pressure increased until the pouch became large enough to hold accumulated food and mucus from the esophagus. The accumulated material would also tend to increase the size of the pouch. Diverticula throughout the gastro-intestinal tract are not uncommon. They occur quite often in the duodenum and other parts of the small intestine, especially as a Meckel's diverticulum. Diverticulitis, as it occurs in the sigmoid and other parts of the intestine, is common also, but in all such cases the sac of the diverticulum is composed of all the coats, the mucosa, submucosa, muscular layers, and peritoneum, which make up the viscus from which the diverticulum originates. This is not true of the pharyngo-esophageal diverticulum, as its sac contains only the mucous membrane and submucosa. Occasionally, there may be a band of muscle fibers extending across the sac, but muscle tissue is not a part of the sac wall. So far as I know, hernia of the inner layers of a

2. Brosch, A.: Epibronchiale Pulsions-Divertikel, Arch. f. path. Anat. **162**: 22, 1900; Zur Anatomie und Pathogenese der Vorderwand-Divertikel des Esophagus, Arch. f. path. Anat. **176**:328, 1904.

3. LeCount, E. R.: Epibronchial Pulsion Diverticula of the Esophagus, Tr. Chicago Path. Soc. **10**:35, 1915.

4. Zenker, F. A., and Ziemssen, H.: Krankheiten des Esophagus, Ziemssen's Handbuch der speciellen Pathologie und Therapie, Leipzig **7**:208, 1874.

viscus through a separation in the outer layers to form a diverticular pouch occurs in only one other region, and that is in the urinary bladder. The diverticular sac of an esophageal diverticulum and the sac of a bladder diverticulum are formed in identically the same manner. The sac of a diverticulum of the bladder is also composed largely of mucosa and submucosa, and contains very little if any muscular tissue.

From a review of the histories of our cases, we were unable to obtain any other clue to the etiology than the weakness in the wall of

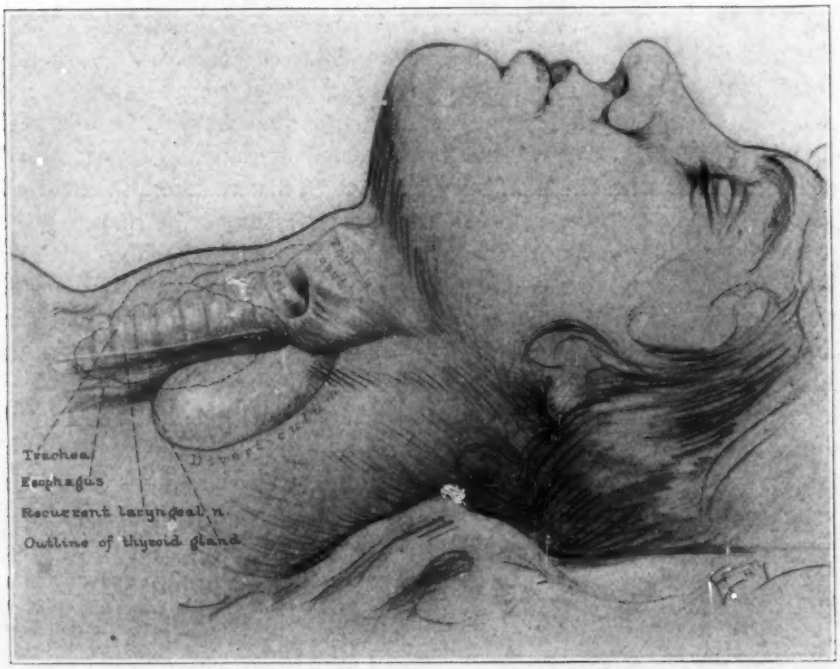

Fig. 1.—The usual position of the diverticulum on the left side of the neck behind the esophagus.

the upper end of the esophagus. There had been no history of trauma or any evidence of anything unusual in mastication or deglutition. The first symptom noticed in nearly all cases was dryness in the throat and a gradually increasing difficulty in swallowing. The sensation of some foreign material in the throat was often mentioned. These symptoms led to accumulations of mucus, and later undigested particles of food were raised. Dysphagia and a gurgling noise in the throat are mentioned as an early symptom by nearly all patients. As the sac increases in size, the patient has the sensation of pressure and often the esophagus closes, so that there is almost a complete stenosis of the

lumen. This sometimes leads to the diagnosis of carcinoma or stricture for which not a few of these patients have been treated. None of our patients had had symptoms during early life that would indicate this condition. The symptoms very rarely appeared until the patients were 45; in our series of fifty-four cases, the average age at the time of operation was about 55, and the symptoms had been present on an average of about six years. If the sac is large and filled, it can usually be felt and seen in the neck. Although the communication of the sac with the esophagus is in the midline, the sac itself is more often on the left side and sometimes when it cannot be seen or felt, its contents

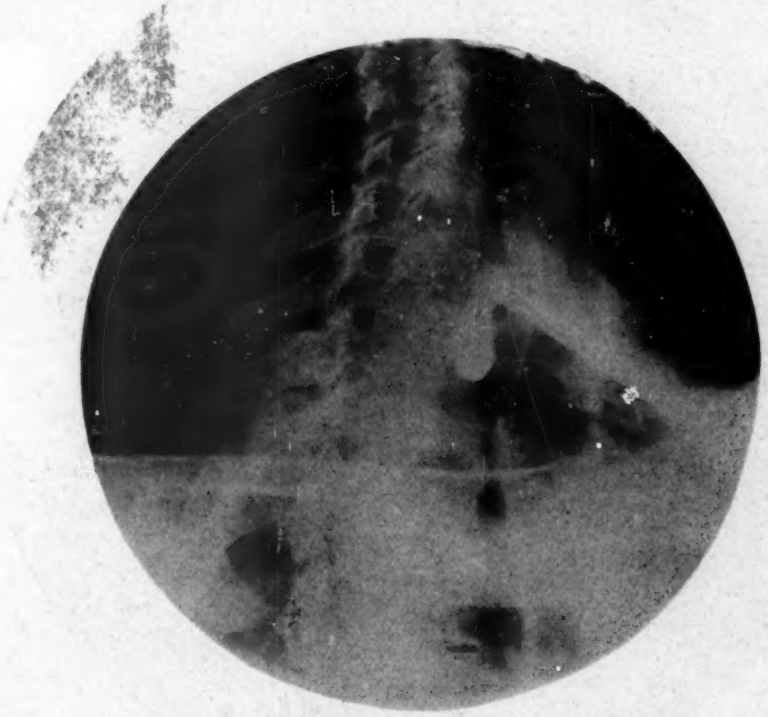

Fig. 2.—Type of esophageal diverticulum.

may be expressed by pressure with the fingers on the left side of the neck. The size of the sac varies greatly. In some instances, it is just large enough to be made out, and in other instances it is so large that it occupies the greater portion of the upper mediastinal space. Usually the symptoms are proportional to the size of the sack, although sometimes a small sac is placed so as to make more trouble than a larger sac.

DIAGNOSIS

Before the development of roentgen ray and esophagoscopic examinations, it was often quite difficult to make an accurate diagnosis in

cases of esophageal diverticula and many complicated and inaccurate tests were carried out. Now an accurate diagnosis can be made by either one or both of these methods. If the histories suggest a possibility of the condition, it is our custom to have a roentgenologic examination made of this region after the patient has swallowed a bismuth mixture, and the diverticulum is revealed in practically every

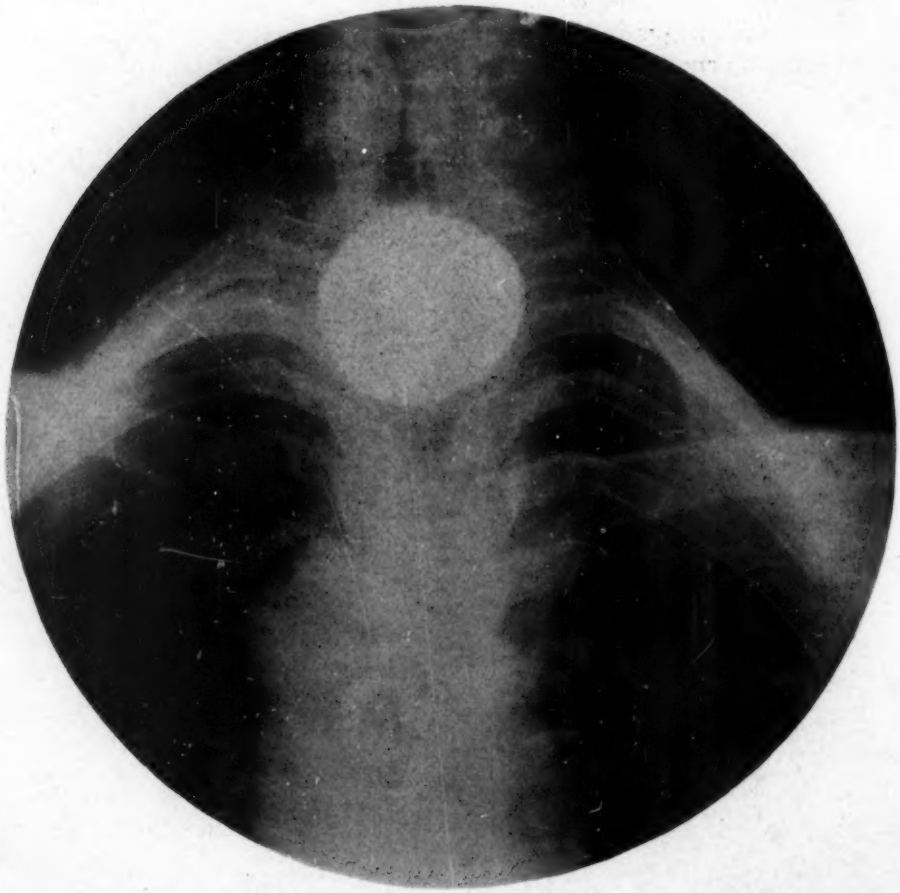

Fig. 3.—Type of esophageal diverticulum.

case (Figs. 2, 3 and 4). After this an esophagoscopic examination is made to rule out the possibility of other lesions, such as a stricture below the diverticular opening, or any other condition in the lower end of the esophagus. The examination, as carried out in the clinic by Carman, Plummer and Vinson, of these cases of lesions of the esophagus, which were not so well examined or understood a few

years ago, now places them among our most satisfactory cases. The improvement in the treatment is very largely due to knowledge obtained through these examinations.

In the differential diagnosis, dilatations of the esophagus must be excluded; they are usually due to spasm at the cardia (Fig. 5) or stricture of the esophagus due to scar, or, as in one case in our series,

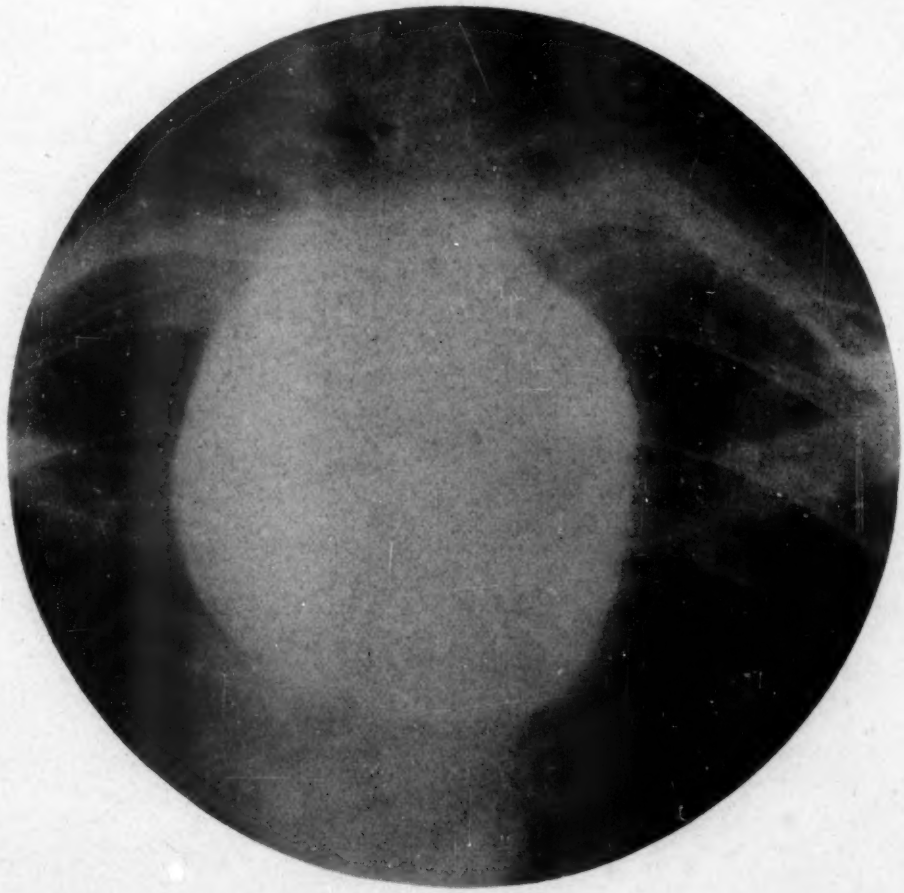

Fig. 4.—Type of esophageal diverticulum.

stricture apparently due to a congenital diaphragm. In this case (Fig. 6), the roentgenogram more closely resembled the picture of a diverticulum than any other we have seen, and yet the age of the patient, 20 months, almost ruled out the possibility of a diverticulum. From the roentgen-ray examination alone, it seems to me, it would be difficult to decide that the lesion was not a diverticulum, particularly since the pouch occurred in the location that a diverticulum would

assume. The methods used by Plummer and Vinson, however, enabled them, by one dilatation, to cause the pouching entirely to disappear. In this case, in which a pouch had formed above a stricture, the sac consisted in a dilatation of the esophagus, and not of a diverticulum.

The symptoms of stricture caused by carcinoma are often similar to those of diverticulum. These conditions occur at the same age, but

Fig. 5 (Case 304841).—Cardiospasm with diffuse dilatation of the esophagus.

the roentgen ray and the esophagoscope clearly differentiate the two (Fig. 7).

TREATMENT

The treatment of esophageal diverticula is surgical. In some of the cases in which the diverticular sac is small, the symptoms may be relieved by dilating the esophagus, and the patients can be kept fairly

comfortable by repeating the dilatations at intervals (Mixter[5]). In most cases, however, there is a tendency for the sac to increase in size until it is so large and deforms the esophagus so much that it stops almost all, or all, of the food, and extreme emaciation results. Some of the patients come for treatment in a starved condition, and require forced feeding before any treatment for the diverticulum can be under-

Fig. 6 (Case 311960).—Stricture of the upper esophagus, probably congenital, in a child, aged 20 months. Roentgenogram identical to that of a pharyngo-esophageal diverticulum.

taken. Sometimes they learn to feed themselves with a tube, and in rare instances it is necessary to form a gastrostomy for feeding before anything further can be done. The early operations for the removal

5. Mixter, S. J.: Congenital Esophageal Pouch, Excision, Immediate Suture of Esophagus, Recovery, Tr. Am. Surg. Assn. **8**:357, 1895.

of the diverticular sac were attended with a high mortality. This mortality was due to infection which occurred at the site of the operation and extended downward into the mediastinum.

Three types of operation may be employed. In the first, described by Girard [6] and Bevan,[7] the sac is dissected from its bed behind the esophagus and in front of the vertebra. After the neck of the sac

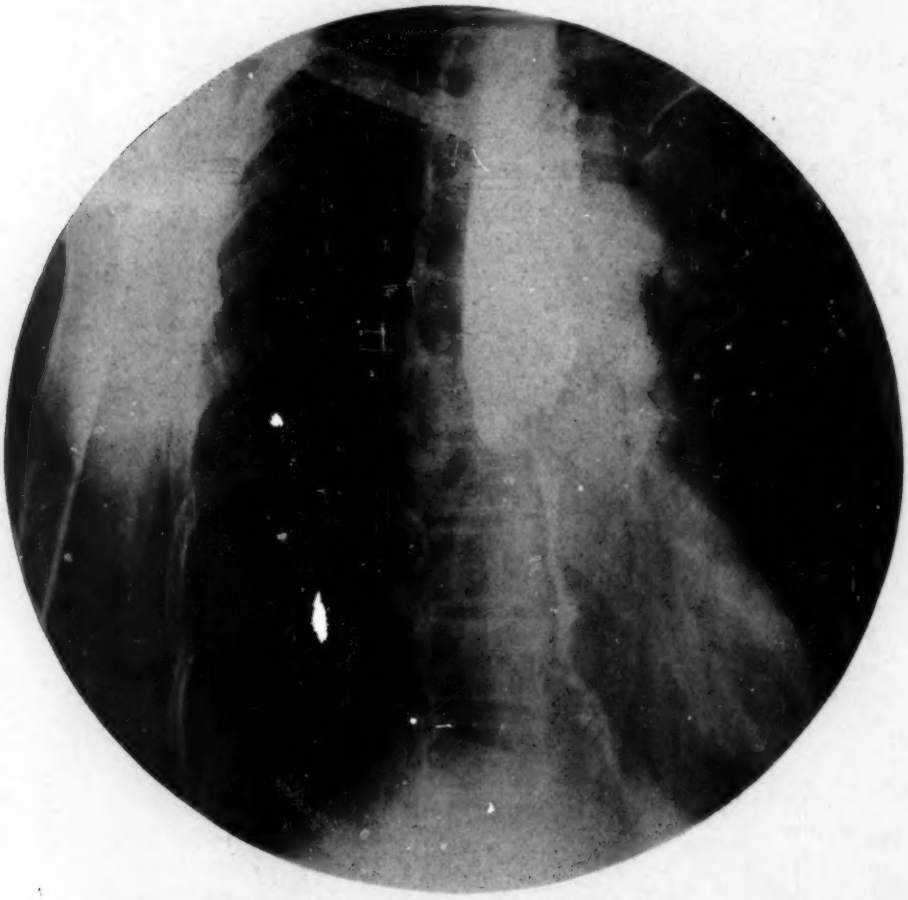

Fig. 7 (Case 283977).—Carcinoma of the middle third of the esophagus.

has been completely freed from the surrounding tissues, purse-string sutures and plicating stitches are placed so that when the sac is tucked into the esophagus and the stitches are tightened, the sac will be per-

6. Girard, C.: Du traitement des diverticules de l'oesophage, Cong. franç. chir. **10**:392, 1896.

7. Bevan, A. D.: Pulsion Diverticulum of the Esophagus; Cure by the Sippy-Bevan Operation, Surg. Clinics, Chicago **1**:449 (June) 1917.

manently held in the lumen of the esophagus where it atrophies or possibly sloughs off. This method of operating is applicable in cases in which the sac is small. We have employed it several times, and with the exception of one case in which there was a small recurrence, it has been satisfactory.

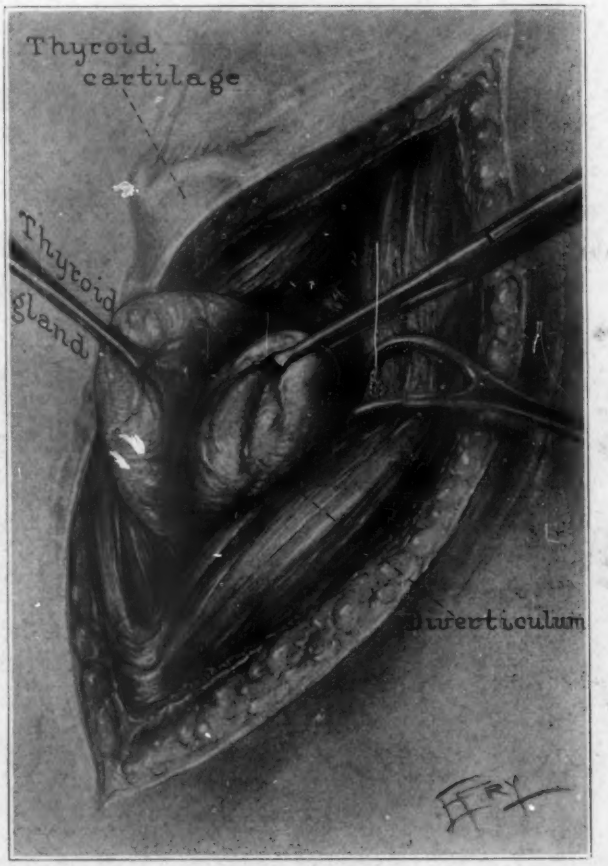

Fig. 8.—The thyroid gland pulled aside to bring the diverticulum into view.

The second method is the one formerly used a great deal, that is, the complete excision of the sac and suture in one stage. This operation is undoubtedly the ideal one and is satisfactory in many cases, but in our experience, in the occasional case there is a certain amount of leaking from the suture line before the pocket behind has become lined with a granulation barrier, and in some cases the result is serious.

The third method is the two-stage operation suggested by J. B.

Murphy [8] and C. H. Mayo.[9] The first stage consists in freeing the sac in the usual manner from the surrounding tissues and dissecting the mucous membrane 1 to 2 cm. from the musculature of the esophagus (Figs. 8 and 9). At this point the neck of the sac is caught to the sternomastoid or even to the platysma muscle with a few interrupted catgut sutures, the wound in the neck is closed around the neck of the

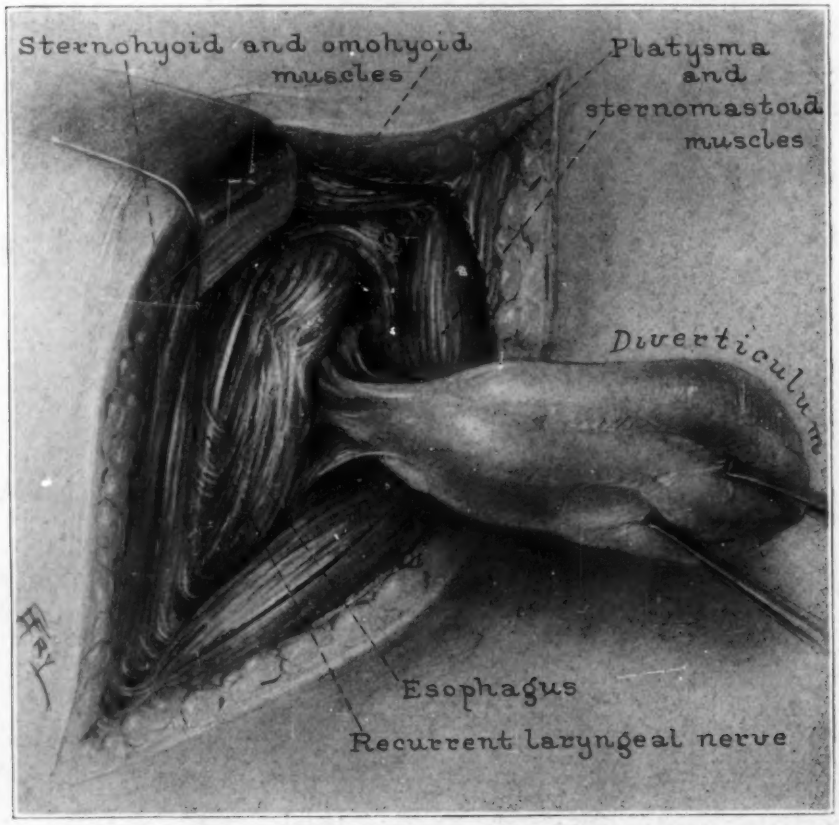

Fig. 9.—The diverticulum freed, and the neck and the attachment to the esophagus exposed.

sac, and the entire sac is allowed to prolapse from the wound. Neither the esophagus nor the diverticular sac is open so that the surrounding tissues and spaces are not exposed to any infection. By the removal of the sac from its place behind the esophagus, the deformity in the

8. Murphy, J. B.: Diverticulum of the Esophagus, Conservative Treatment, Surg. Clinics, Chicago **5**:591, 1916.

9. Mayo, C. H.: Diagnosis and Surgical Treatment of Esophageal Diverticula; Report of Eight Cases, Ann. Surg. **51**:812, 1910.

esophagus is corrected and immediately afterward the patient swallows without difficulty. The sac is left in this position for ten or twelve days, during which time the patient is able to be up and around, and can leave the hospital if he wishes (Fig. 10). Murphy advised twisting the neck of the sac before suturing it to the muscles. In some cases we have followed this plan, although in a few the distal part of the sac sloughed as a result of reduced circulation. The only difference in these cases was that small esophageal fistulas persisted for a short time, and for this reason I believe that it is better not to

Fig. 10 (Case 313455).—Patient three days after first stage of two-stage operation.

twist the neck of the sac. Usually at the end of ten or twelve days, the patient returns to the operating room. At this time there is a complete barrier of granulation tissues which separates the pocket in the neck and the mediastinum. In the second stage it is not necessary to use an anesthetic of any kind. In some instances it may be well to inject the neck of the sac with procain before excising it. The neck of the sac is again freed, the sac excised, and the opening in the esophagus and the wound in the neck are closed (Fig. 11). In some instances a small fistula forms, although it always heals completely within a short time. In one case in which the diverticulum was very large and in which there had been considerable deformity of the esophagus,

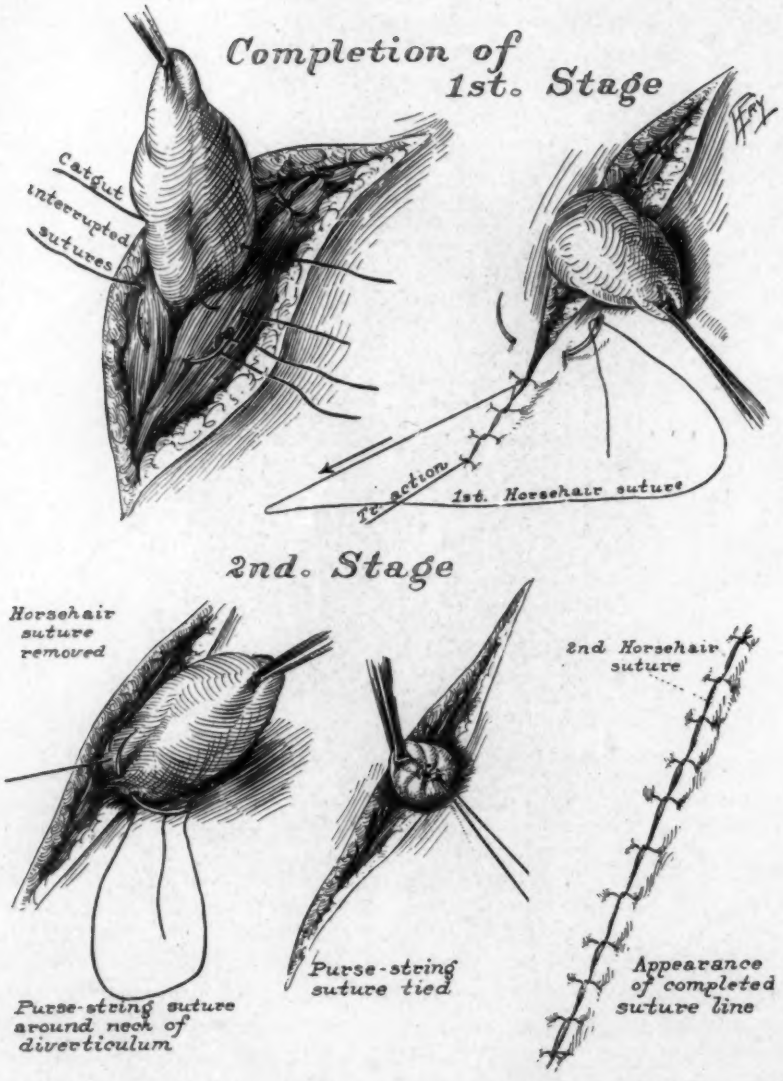

Fig. 11.—Prolapse of diverticulum from the wound at the end of the first stage of the operation. Freeing and excision of the sac at the second stage.

the fistula persisted for a number of weeks and it was necessary to make a secondary closure. In all other cases the wound healed primarily or within a few days after the second-stage operation (Fig. 12).

The two-stage procedure simplifies the operation greatly and is infinitely safer than the complete excision of the sac in one stage; the inconvenience to the patient and the time and suffering are also less than they would be if complete excision were performed in one stage.

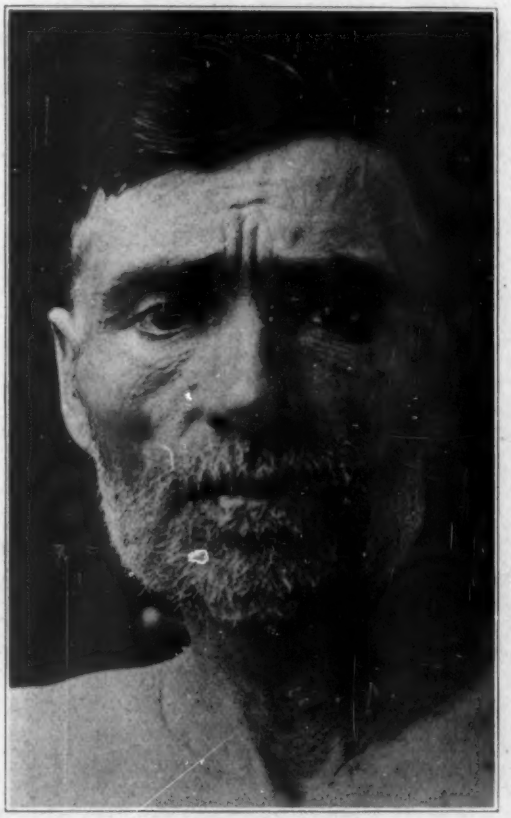

Fig. 12 (Case 313455).—Patient shown in Figure 10. Wound healed and in good condition ten days after removal of diverticulum at second stage of two-stage operation.

In many of our early cases the one-stage operation was performed, but the two-stage operation is so safe, I believe, that it should be employed in nearly all instances. If infection occurs following the one-stage operation, it results fatally in many cases. Of late I have used the two-stage operation in cases in which the sac was small and it has been satisfactory.

OPERATIVE RESULTS

We have operated in fifty-four cases of esophageal diverticula with three deaths; two are included in my former report of thirty-five cases. Two of the patients died following a one-stage operation, the third following the first stage of a two-stage operation.

The ultimate functional results have been very satisfactory. One patient was operated on for recurrence, and in one or two cases a sound has been passed because the esophagus seemed too small, but in no instance has a stricture developed.

MANAGEMENT OF DIRECT INGUINAL HERNIA

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The problem of inguinal hernia has resolved itself into the management of the direct variety. This statement is based on the fact that all surgeons agree that in indirect or oblique hernia the results following operation are excellent, provided it is performed properly and according to one of the approved methods. No such claim can be made for the operative results in direct hernia, nor can it be said that we have a standardized operation for this condition. Many surgeons recognize the futility of the usual technic for indirect hernia when applied to the direct type, and various modifications of recognized procedures have been devised in the effort to correct the inherent anatomic defects that give rise to this form of rupture. Up to the present time, however, none of these modifications have proved satisfactory in all cases, and I, for one, have reached the conclusion that a certain number of direct hernias cannot be cured by operation.

The difficulty lies in selecting the cases suitable for operative treatment. It is not an uncommon experience in what seemed to be a most favorable case to have the patient return with an early recurrence, and on the other hand, of having a most unfavorable case result in a permanent cure. As a rule, however, the patients in whom recurrence is almost sure to take place belong to a definite group. They are usually thin men with poorly developed muscles in both lower quadrants. Coughing or strain produces a general bulge extending from above the anterior superior spine over to the margin of the rectus, and down to the external ring, with a more or less marked hernial protrusion about the middle of the inguinal canal or at the ring. Palpation of the inguinal region may reveal a positive separation in the external oblique aponeurosis; or by invagination of the scrotum, one or more fingers may be inserted into the external ring and passed directly backward, revealing almost complete absence of the conjoined tendon. In other words, not only is the roof to the inguinal canal weak, but the floor is formed principally of transversalis fascia and peritoneum.

To the foregoing group may be added certain persons who have accumulated considerable fat over the lower abdomen. This fat obscures the condition of the underlying muscles and also interferes with proper palpation. The unfavorable outlook in this class of cases may not be recognized until after the patient comes to operation. The man with weak muscles and a small bulge at the lower part of the

inguinal canal is not infrequently referred to the surgeon for operation by examiners for industrial corporations and civil service boards before being given employment. It would be far better in many instances for both the employer and the patient if a light truss was applied and a note made on the application form to the effect that the result following operation would probably prove unsatisfactory on account of poor muscles, that the slight hernia was in no way incapaci-

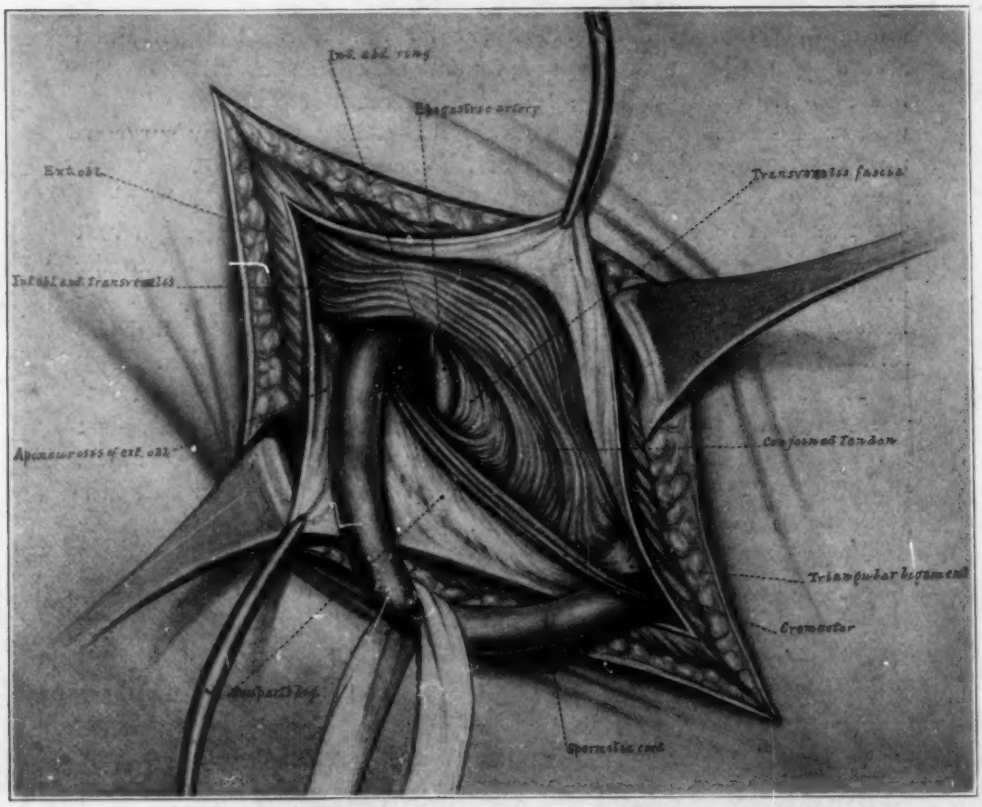

Fig. 1.—Anatomy of inguinal region.

tating, and that with proper support it would not be made worse by ordinary work. Let the employee accept the position with this understanding and assume the responsibility. If, on the other hand, operation is performed with the chances of an early recurrence, the corporation or state becomes responsible.

No better evidence could be had of the value of the foregoing suggestion than the attitude taken by the officials responsible for the regulations governing the draft in our recent army. At first, any man

was accepted by the army after he had undergone a so-called radical cure operation for hernia, without especial attention to the type of hernia, length of time following operation, or to the surgeon by whom it was performed. Later, all men between the ages of 21 and 31 with hernia were accepted by the army. If the time between examination and date of call permitted, these men could go where or to whom they chose for operation; if not, they were forced to be operated on immediately after reaching camp. Finally, in the last draft no man with

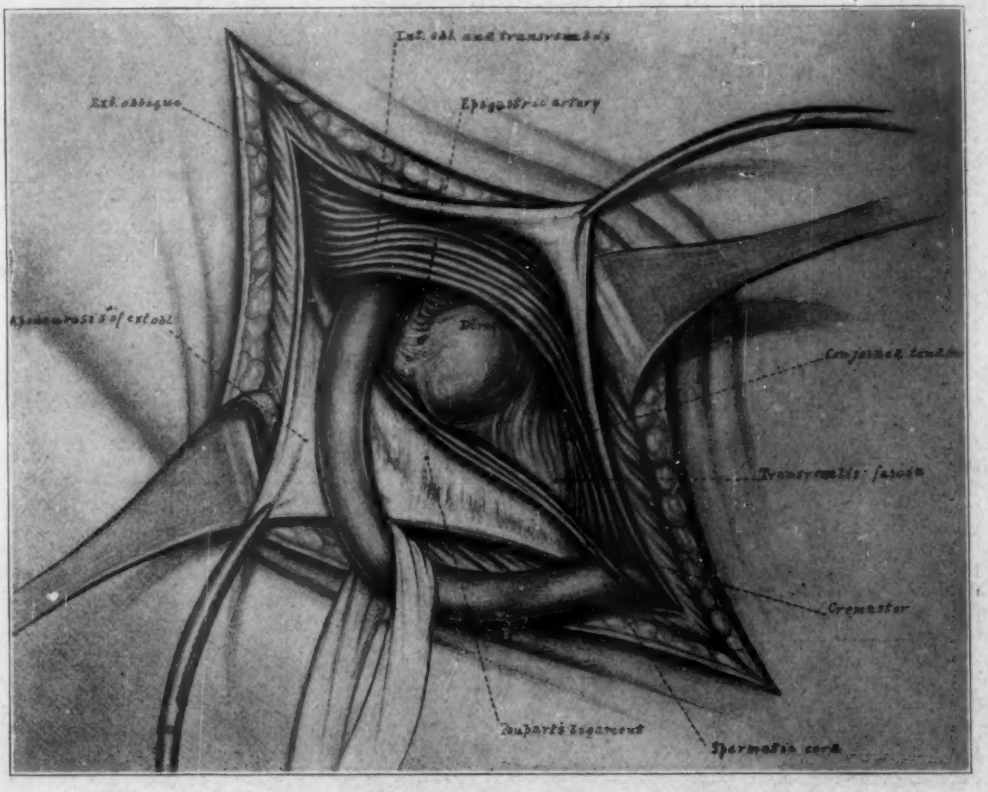

Fig. 2.—Direct inguinal hernia.

hernia was accepted for full military duty either before or after being operated on. From these changes in the regulations, it is quite evident that the results following herniotomy were not so satisfactory as had been anticipated. While some of the recurrences in soldiers may have been the result of poor technic, I venture to state that the great majority occurred in hernia of the direct variety, and that a good percentage of these were of the type which should never have been operated on. Aside from the disappointment to the surgeon in having recurrence take place, the patient himself deserves more consideration;

for, after all, it is he who has to suffer the consequences. We often console ourselves with the thought that even if the hernia does return it will not be so bad or so hard to control by a truss as it was before operation. When the loss of time, the danger of going through an operative procedure, even though very slight, and the occasional risk of complications are taken into consideration, are we quite justified in operating except for good reason in this type of case when we know from experience that the result is likely to be unsatisfactory?

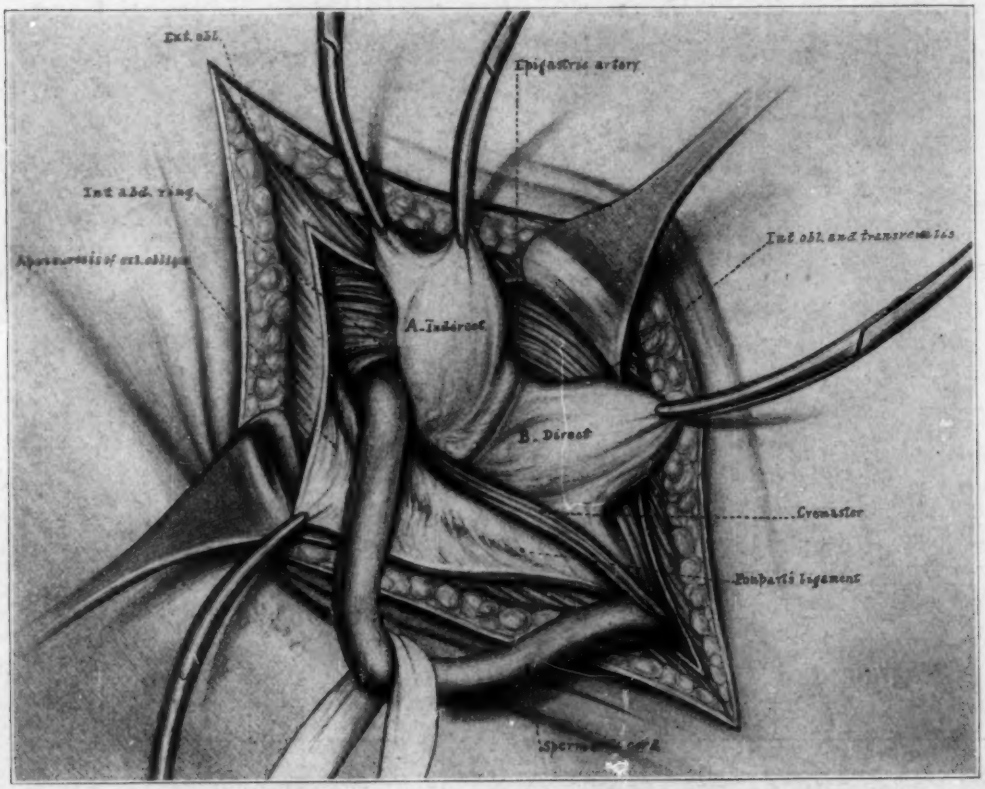

Fig. 3.—Combined direct and indirect hernia—"pantaloon sac."

ANATOMIC CONSIDERATIONS

A correct knowledge and clear understanding of the anatomy of the inguinal region (Fig. 1) is necessary in order to obtain satisfactory results from the operative treatment of hernia. Without this knowledge there is little satisfaction to the surgeon, and a grave injustice may be done the patient. Paradoxical as it may seem, the wonderful results obtained in recent years following operation in the indirect inguinal hernia group, which comprises more than 90 per cent. of all

hernias, is largely responsible for the number of failures in the cases of direct hernia. The explanation is that many surgeons have come to look on the hernia operation as of almost minor importance, and pass these patients along to young assistants or house surgeons without proper supervision, with the result that if the anatomy or the arrangement of the sac is unusual, the operation is likely to prove a failure.

For the purposes of this paper, I shall speak of the inguinal region as that triangular part of the lower abdominal wall bounded

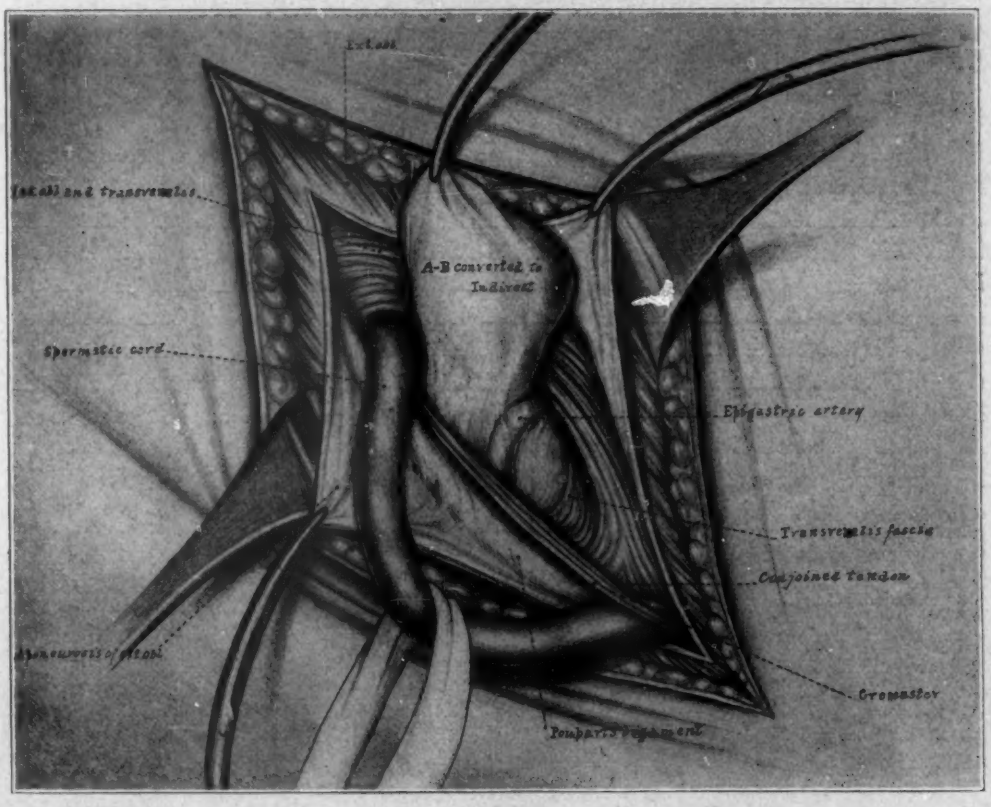

Fig. 4.—Combined sac converted into indirect hernia.

below and to the outer side by Poupart's ligament, internally by the margin of the rectus, and above by a horizontal line extending from the anterior superior spine to the rectus muscle. The structures to be studied in the dissection of this area are the external oblique, internal oblique and transversalis muscles, including the cremaster muscle; the rectus muscle and its sheath, the conjoined tendon and transversalis fascia; also, the iliohypogastric and ilio-inguinal nerves, and the deep epigastric artery.

The external oblique muscle, the fibers of which run down and in, may be referred to as the roof of the triangle. It is usually a firm aponeurotic structure extending as Poupart's ligament from the anterior superior spine to the pubic bone on the outer side, and to the linea alba on the inner. It presents at its lower inner portion an opening known as the external abdominal ring, which should normally admit the tip of the finger. The portions of the internal oblique and transversalis muscles encountered in the dissection arise from the

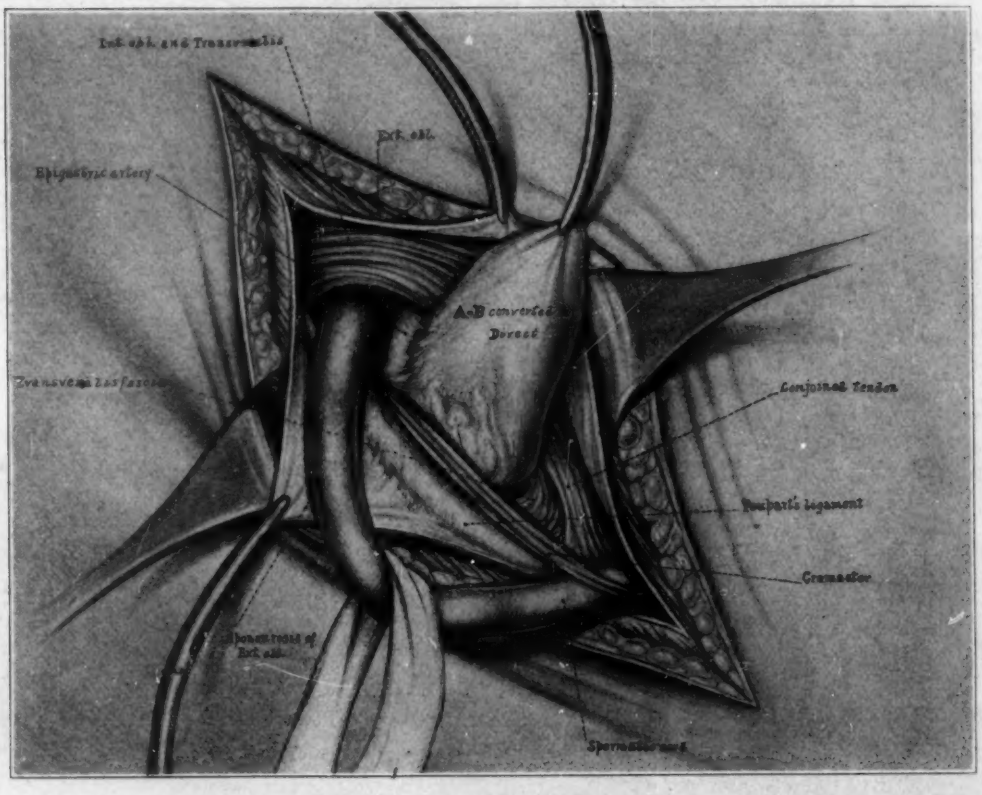

Fig. 5.—Combined sac converted into direct hernia.

outer half to the outer third of Poupart's ligament. The former usually appears as a well-developed muscle arching down and in, completely overlapping the latter. The two blend into a common aponeurosis, which becomes part of the anterior sheath of the rectus in its lower fourth and is continued down to be inserted into the pubic crest and pectineal line — the latter portion forming the conjoined tendon. This tendon, extending laterally from the margin of the rectus muscle, lies just behind the external ring and in front of the

transversalis fascia. Its thickness and width vary in different persons, but when well developed it is of considerable value in the prevention of direct hernia. The cremaster, a thin layer of muscle fiber surrounding completely or in part the spermatic cord, has its origin at the lower margin of the internal oblique.

The transversalis fascia — a fairly thick fibro-aponeurotic structure — may be said to form the floor of this triangular area. The inner portion of this fascia is composed of more or less vertical fibers

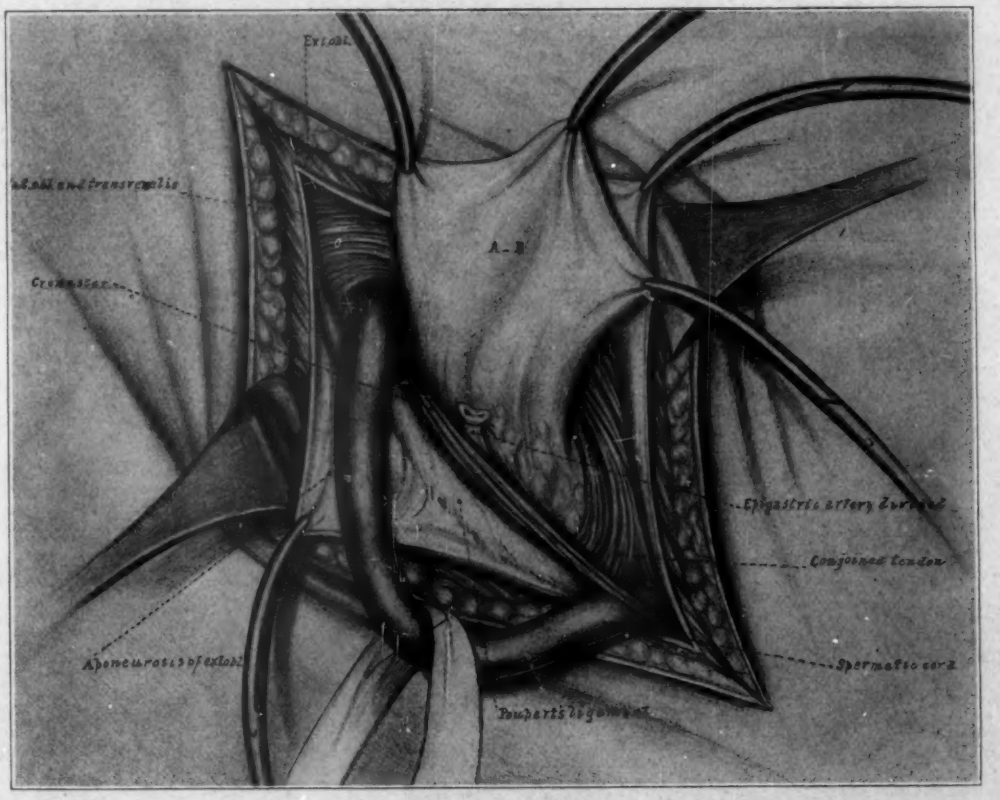

Fig. 6.—Combined sac converted into single sac by dividing epigastric artery.

of considerable strength; the outer is made up of arching fibers through which the cord passes, forming the internal ring. The middle portion, lying just below and internal to the deep epigastric artery, is the thinnest part of the fascia, and constitutes the weakest point in the floor. It is through this weak middle part that the great majority of direct hernias occur.

The deep epigastric artery — a branch of the external iliac — lies between the transversalis fascia and peritoneum, and runs on a line

from the middle of Poupart's ligament to the umbilicus. This artery forms the lower boundary of the internal ring, and is the most important landmark in this region, as the variety of a given hernia is determined by the relation of the neck of its sac to this vessel. The ilio-hypogastric and ilio-inguinal nerves — the former running along the anterior surface of the internal oblique to the margin of the rectus muscle, and the latter through the inguinal canal to the external ring — are both sensory in this location, but should be preserved. The inguinal canal, about 1½ inches in length, occupies the lower

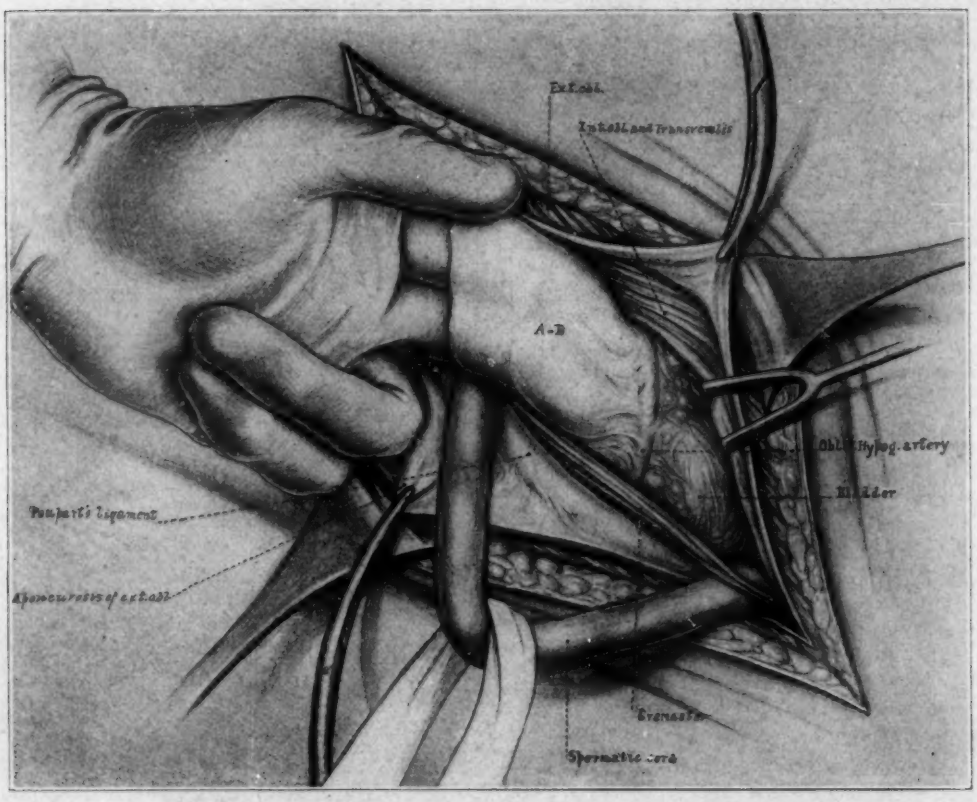

Fig. 7.—Sac opened showing properitoneal fat and bladder.

outer part of this area, and runs down and in from the internal abdominal ring to the external ring at the pubic spine. It is occupied by the cord in the male, and round ligament in the female. The sacs of all hernias situated in this region bear a definite relation to this canal. The oblique or indirect hernias enter it at the internal ring and when complete traverse its entire course. The usual form of direct hernia, forcing its way through the transversalis fascia, enters

the canal at some point below the deep epigastric artery and appears at the external ring or not, depending on the size of the sac.

Direct hernias constitute about 10 per cent. of all primary inguinal hernias. On the other hand, considerably more than 50 per cent. of secondary or recurrent inguinal hernias are of this variety. This large proportion of direct recurrences indicates either that the usual operation for this type of hernia is inadequate or that the primary hernia existed as a combined direct and indirect hernia, and the direct por-

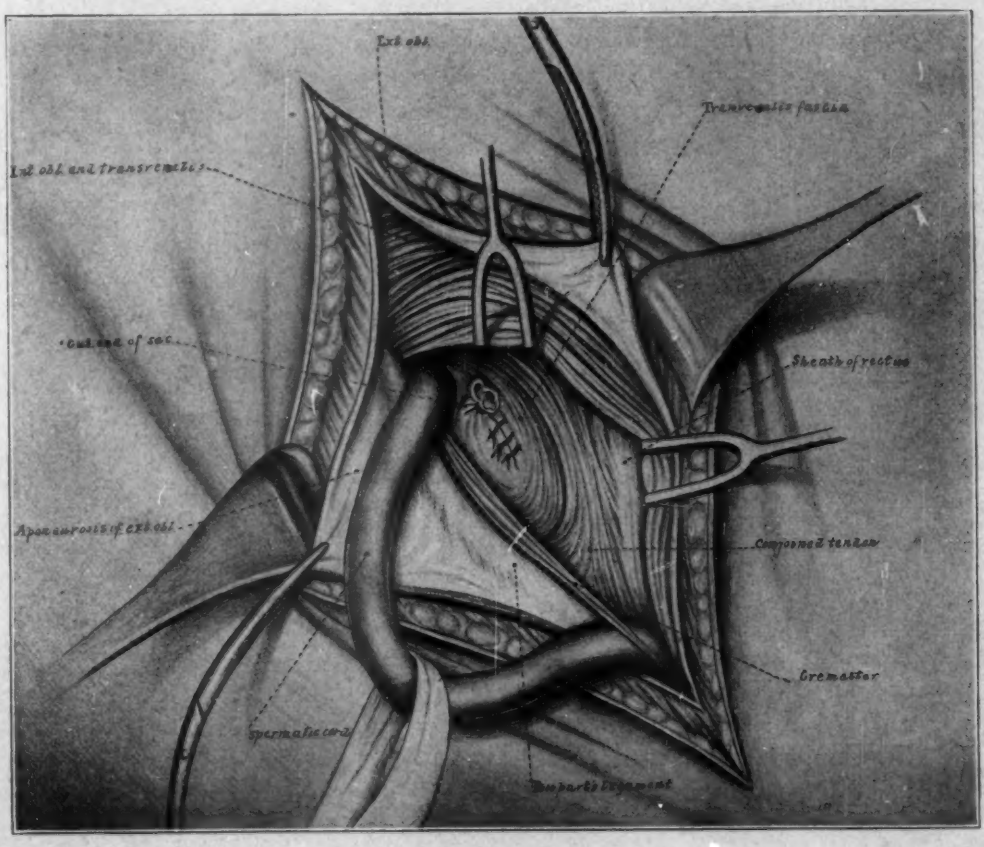

Fig. 8.—Neck of sac closed.

tion of the sac was overlooked or the cases were improperly selected. The typical form of direct hernia (Fig. 2) appears just below the deep epigastric artery through the weak middle portion of the transversalis fascia, and has, besides peritoneum, properitoneal fat and fascia, the cremaster muscle as a covering. However, not infrequently the cremaster with the cord lies entirely to the outer side of the sac. The combined direct and indirect hernia — the so-called pantaloon

sac — one portion of which appears above the deep epigastric artery and the other below (Fig. 3), occurs perhaps half as frequently as the typical form. In this type either sac may constitute the major portion of the hernia, or the two may be of equal size. Rarely a direct protrusion occurs through the lower thick segment of the transversalis fascia some distance below the epigastric artery, and at times the sac may be divided into two portions by a band of fascia. An entirely different form of hernia, erroneously classed as direct inguinal, is occasionally found in the lower inner portion of this region (Fig. 16). It appears in the linea semilunaris just above the pubic bone, and is very probably due to properitoneal fat working its way through one of the perivascular spaces. The peritoneum is dragged along with the fat, and the protrusion occurs between the margin of the rectus and the conjoined tendon, or pushes the latter structure ahead of it as one of its coverings. This hernia, usually small, although it may become of considerable proportions, resembles to a marked degree the femoral type in that it is globular in shape, contains much peritoneal fat, and has a narrow neck with sharp margins. The location of this protrusion is the only reason that can be given for grouping it under the general heading of direct hernia, as in no way does it conform to the essential requirements necessary for such classification. Hernia of the linea semilunaris may exist coincidentally with direct or indirect hernia, and may also occcur at other points in the linea semilunaris. These protrusions are similar in nature to the epigastric hernia situated at or near the median line.

CAUSES, SYMPTOMS AND DIAGNOSIS OF DIRECT HERNIA

Direct hernia occurs most often in men between the ages of 25 and 45. It is occasionally seen in younger persons, and has even been reported in children. It is rare in women. Poorly developed or deficient musculature in the lower half of the abdominal wall may be said to be the underlying cause in practically every instance. Many of these patients have a narrow pelvis, with Poupart's ligament and the fibers of the external oblique muscle taking an almost vertical course. The portion of the internal oblique and transversalis muscles arising from Poupart's ligament, which usually consists of heavy muscular fibers extending well down over the internal ring and upper part of the inguinal canal, may be replaced by a thinned aponeurotic layer with a short muscular belly leaving the normally weak portion of the transversalis fascia with little or no support. The rectus muscle is likely to be narrow and thin. As no preformed peritoneal pouch or protrusion exists at the point in the floor of the inguinal region where

direct hernia usually occurs, it is, strictly speaking, classed as of the acquired variety; however, the above described condition of the muscles in this region is unquestionably of congenital origin in many cases. The form of occupation of the patient does not seem to be responsible for the development of the hernia. It is conceivable that the condition will appear earlier in those doing hard labor than in those doing light work, but it is a fact that many of these hernias are seen in tailors,

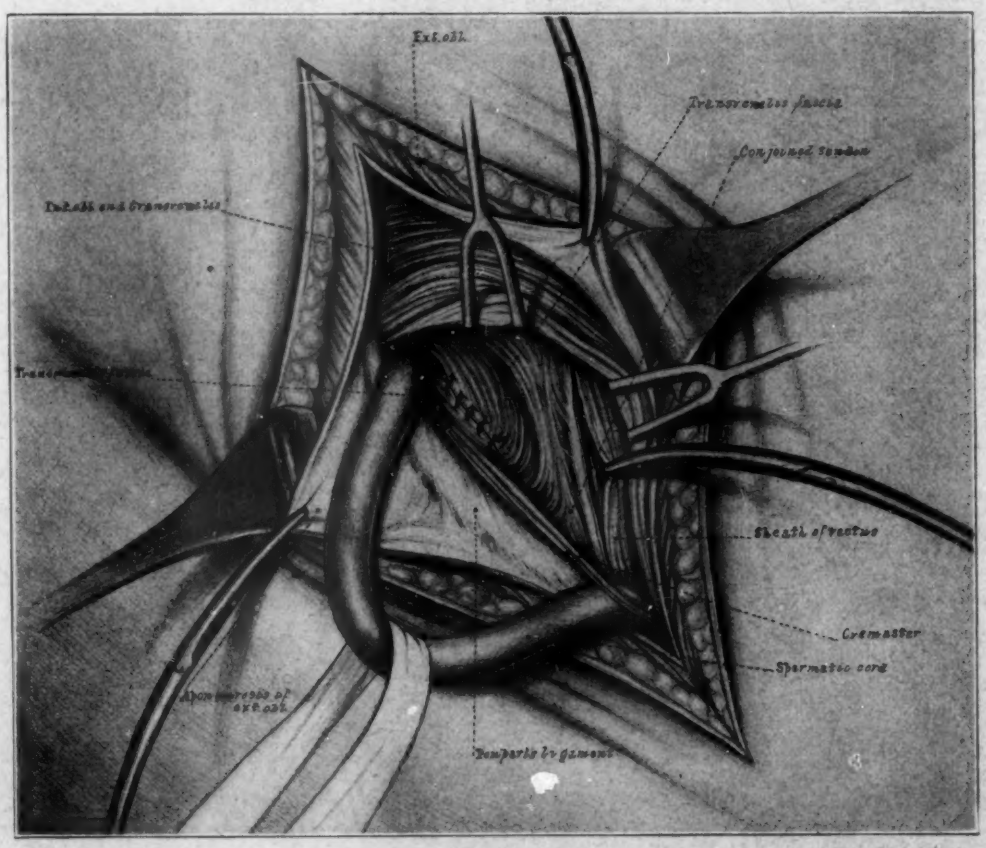

Fig. 9.—Closure of transversalis fascia as a separate layer; sheath of rectus opened.

clerks and bookeepers. The majority of direct hernias develop without giving rise to symptoms. Either the man notices a painless swelling in the inguinal region, or his attention is called to such a swelling while undergoing a physical examination for one reason or another. A certain number of patients will state that after an unusual effort at lifting or straining, they suffered severe pain in the groin and immediately noticed a swelling. Examination fails to reveal evidence

of an acute lesion, as would surely be the case if a trauma had been received of sufficient violence to cause a palpable mass. The extra effort has suddenly forced some portion of the abdominal contents into a sac, which has slowly formed without giving rise to symptoms. Some patients complain of dull pain or a sense of weakness in the inguinal region from the incipiency of the hernia. Once the condition has developed to any extent, the symptoms are those usual to hernia in this region, with the exception that on account of the large size of the neck of the sac in the average case there is little tendency to strangulation.

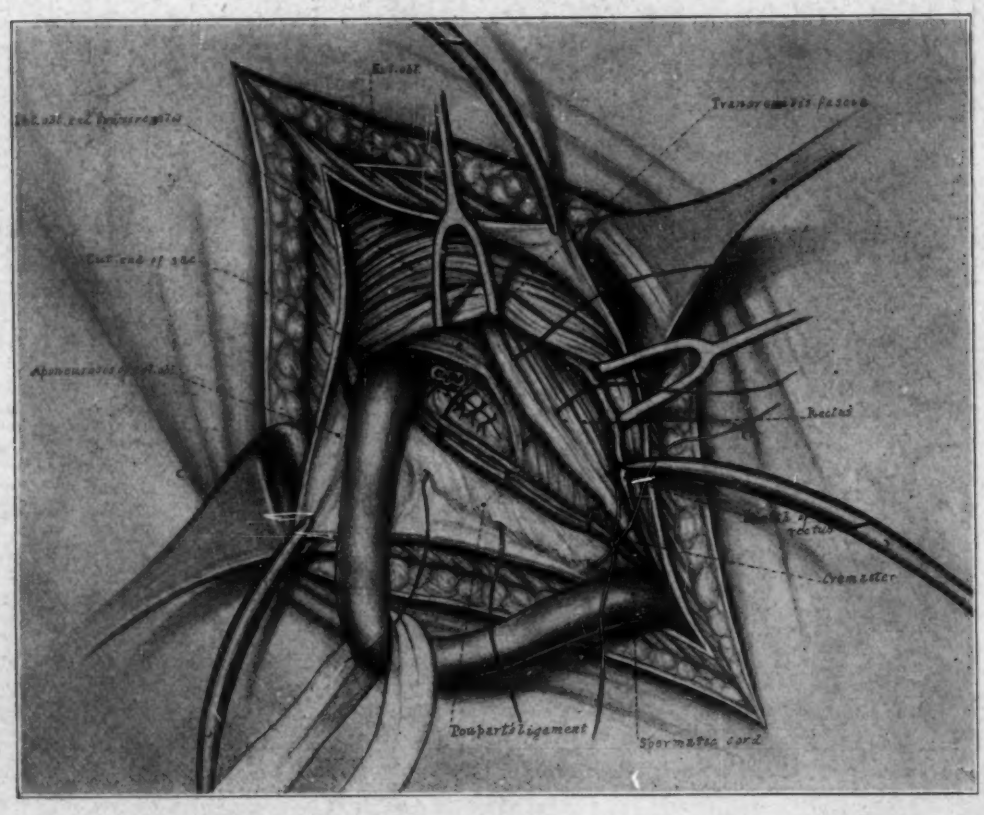

Fig. 10.—Rectus muscle exposed, sutures in place.

If these points are borne in mind, the diagnosis of direct hernia is easily made in most instances: (1) Age and sex of the patient; (2) condition of the lower abdominal muscles; (3) the fact that the protrusion is often bilateral; (4) the situation which is low down over the pubic bone except in very early cases in which the sac has not descended to the external ring; (5) globular swelling which does not

tend to enter the scrotum even if of large size and is easily reducible, and (6) a definite weakness disclosed by palpation over the lower portion of the inguinal canal. By invaginating the scrotum through the external ring, the finger may be passed directly back over the pubic bone, and the margin of the rectus muscle easily palpated. Occasionally, the deep epigastric artery may be felt above. On the other hand, an exceptional case of indirect hernia will present a sufficient number of the physical signs just enumerated to make the differential diag-

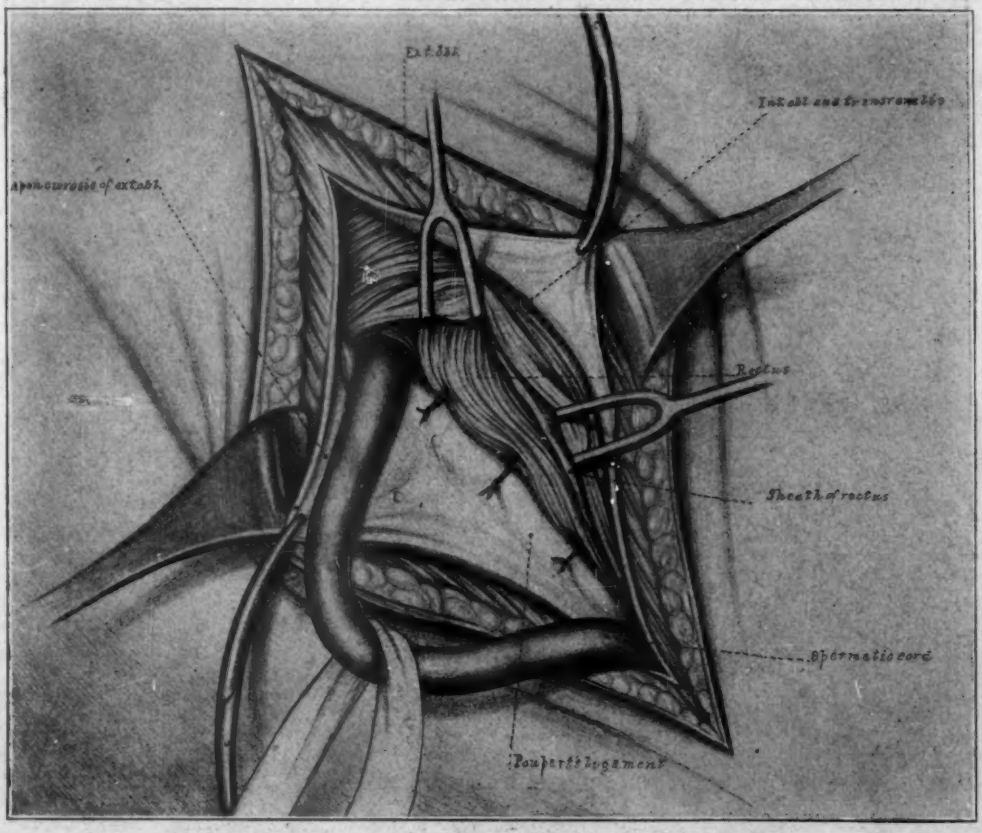

Fig. 11.—Rectus muscle in apposition to Poupart's ligament.

nosis very difficult. It is practically impossible to differentiate direct hernia from hernia of the linea semilunaris. The latter occurs usually in persons with a considerable amount of fat in the pubic region, and for this reason palpation or exploration of the canal with the finger is not satisfactory. I know of no case of hernia of the linea semilunaris in this region that was diagnosed before operation.

TREATMENT OF DIRECT HERNIA

The results obtained in the operative treatment of direct hernia depend in a large measure on the proper selection of cases. Old men with weak muscles and relaxed tissues in general are poor subjects for the plastic type of operation necessary to cure this condition, and except for some very good reason they should not be operated on. The younger men with weak lower abdominal muscles, and an almost vertical pelvis should be examined with great care, and the effort made

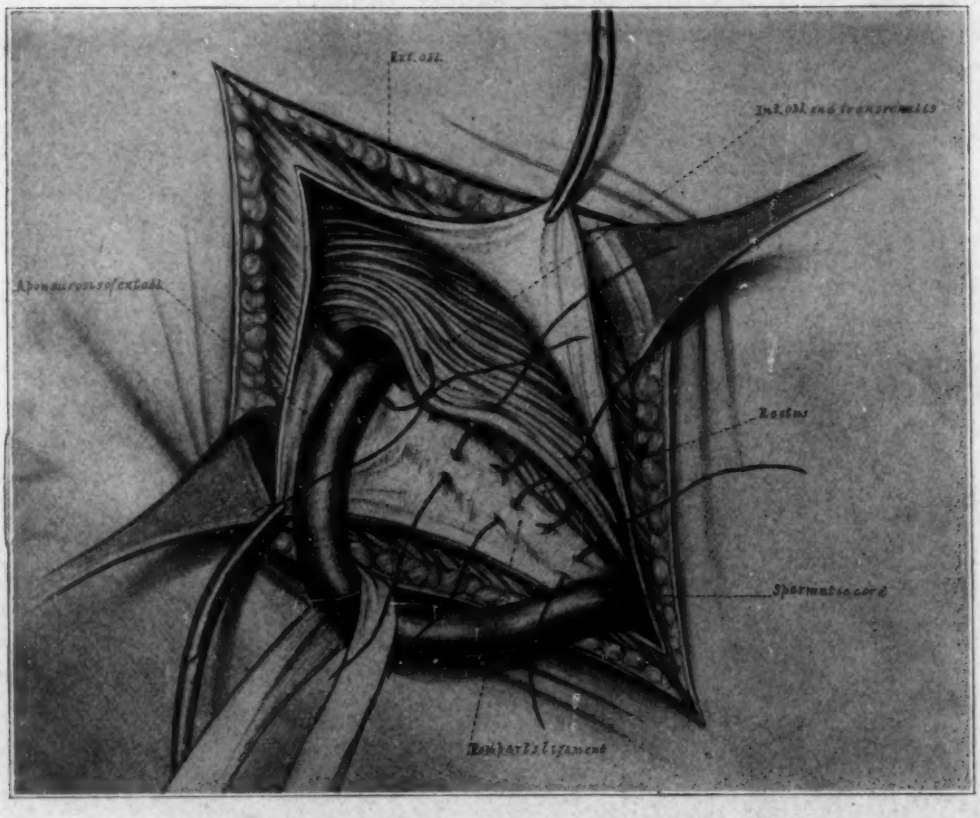

Fig. 12.—Bassini operation after rectus transplantation.

to determine whether by any sort of operation the structures in the inguinal region can be so strengthened as to resist the intra-abdominal pressure which in these patients is apparently greater than the deficient musculature can withstand. The most unfavorable cases for operation are those in which there is a protrusion usually of small size occurring about the middle of the inguinal canal in which the external oblique is relaxed and very thin, or in which there is a separation of its fibers.

The external ring may not admit the tip of the finger; but with the patient lying down, one or more fingers may be passed through the hiatus in the external oblique muscle and the edge of the rectus muscle, or the pubic bone may be palpated. It is in this class of cases that I believe the patient's best interest will be served if a truss is applied just tight enough to balance the intra-abdominal pressure, and systematic exercise of the abdominal muscles advised. If the muscles are improved by the exercise and the hernia persists, the question of

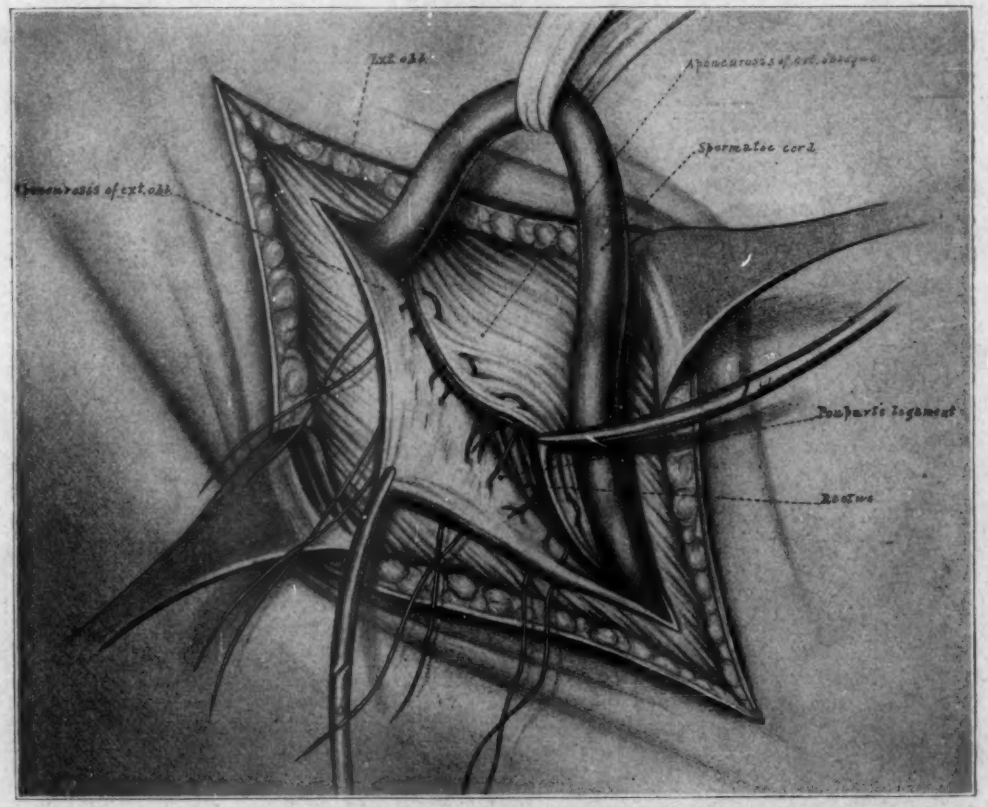

Fig. 13.—Andrews operation after rectus transplantation.

operation may again be taken up in a period of from six months to a year. No patient with a chronic cough should be operated on unless there is danger of strangulation.

In the selection of the proper operation for a given case of direct hernia, just as much care should be exercised as in the selection of cases suitable for operation. While the great majority of these hernias fall into two general groups — the usual form in which the protrusion occurs through the normal weak portion of the transversalis fascia

and the combined direct and indirect type — yet an operation which will prove satisfactory in one case may be wholly inadequate in another. Anatomic variations explain this difference. In one instance, the muscles may be well developed, and any one of the well recognized operative procedures may give a perfect result. On the other hand, the muscles may be thinned out, poorly developed and the sac large, its base extending almost from the epigastric artery to the pubic bone. An entirely different operation is necessary if a satisfactory outcome is to be expected under such conditions. In spite of the fact that it is generally known that the structures differ in this way, many writers continue to group all direct hernias under one heading, and advise a given operative technic for all cases. Frequently, the operation recommended is one of the recognized methods used for the cure of oblique hernia. That this type of operation is inadequate in cases of direct hernia in which the muscles are undeveloped and the conjoined tendon absent or attenuated was recognized by Bloodgood [1] twenty years ago. This author, in an exhaustive report of cases in which operation was performed at the Johns Hopkins Hospital, showed conclusively that if satisfactory results were to be obtained in this form of rupture, something more than the routine technic must be employed. About 1909, I began the use of the transplanted or, more properly speaking, transposed rectus muscle in conjunction with the Bassini operation in the treatment of this class of cases. So many recurrences were taking place in my patients as well as in those of other surgeons with whom I was associated that it became quite evident that the Bassini operation alone did not meet the indications. Accordingly, I adopted the following method, which I have modified from time to time.

OPERATION

The usual skin incision is made, carrying the lower angle down to the pubic bone, as it is important to have a good exposure in the region of the external ring. The aponeurosis of the external oblique is divided well over toward the edge of the rectus muscle, and both flaps are retracted. The sharp margin of Poupart's ligament is then exposed down to the pubic spine. By blunt dissection, the fibers of the cremaster muscle are separated and the cord gently lifted from its bed. A small retractor is now placed under the arched fibers of the internal oblique and transversalis muscles, exposing the internal ring. By gentle traction on the cord, the peritoneal reflection at the internal ring is brought into view and the presence or absence of an oblique hernia quickly determined. This step is absolutely essential and should be carried out before attempting to isolate the direct hernial sac irrespective of its size or location, for in no other way can the error of overlooking the indirect portion of a combined sac be avoided. If no indirect sac is found, the direct is opened on its upper side in order to keep as far away from the bladder as possible. I believe that the sac should be opened in every hernia that is of sufficient size to warrant operation.

1. Bloodgood, J. C.: Johns Hopkins Hospital Report, 1899.

In the well developed cases, the transversalis fascia is thinned out, and as a rule there is little properitoneal fat. In the smaller ones the fascia may be quite firm and a large amount of fat present, causing considerable difficulty in locating the sac. The outer surface of the sac on its lower and inner sides is more or less covered by fat — usually spoken of as bladder fat — but which in reality differs in no wise from the properitoneal fat of other locations. With the finger inserted through the neck of the sac for support, the fat is gently stripped from its surface. As its lower limits is approached, a number of small blood vessels will be seen and a small tonguelike projection of bladder

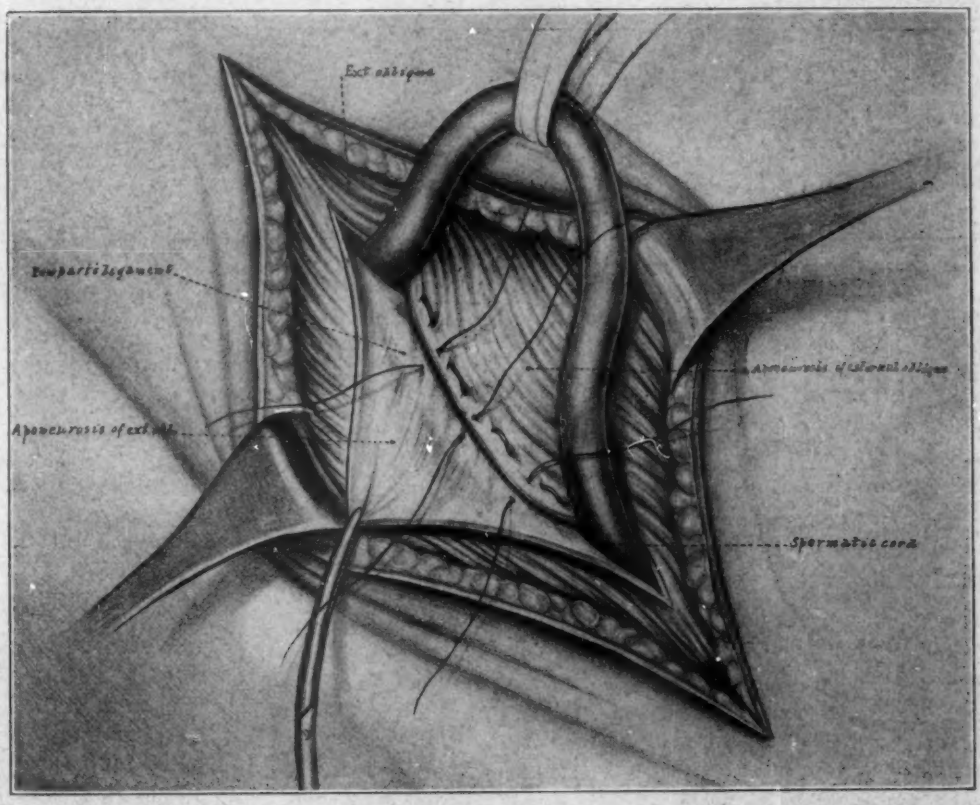

Fig. 14.—Suture of external oblique to Poupart's ligament. Continuous suture is preferred to interrupted, as illustrated.

muscle observed in most cases (Fig. 7). These muscle fibers are rather pale in color and run somewhat parallel to the long axis of the sac. With ordinary care, the bladder should never be injured. The fat is stripped readily as a rule, but occasionally it may be found adherent from the long continued use of a truss. Frequently the obliterated hypogastric artery, a dense fibrous band, will be encountered as the stripping proceeds toward the bladder. This structure, often referred to as indicating the lowest limit to which the fat may safely be removed, is of no value whatsoever as a guide to the bladder. Its location varies in nearly every case. At times it is taut, dividing the fatty mass into

or below it at will. It should be cut if it interferes with proper dissection. After the sac wall has been satisfactorily exposed, its base should be drawn flush with the opening in the fascia and transfixed; or, better still, if of large size, sutured as in the manner of closing the peritoneum in laparatomy wounds (Fig. 8). I always use No. 1 chromicized catgut for this purpose.

In the cases of combined direct and indirect hernia, the two portions of the sac should be converted into one, by drawing one or the other above or below the deep epigastric artery, being guided by their relative size as to whether it is best to convert the direct into an indirect or vice versa (Figs. 4 and 5). I formerly advised dividing the artery in this type of hernia (Fig. 6), but I am

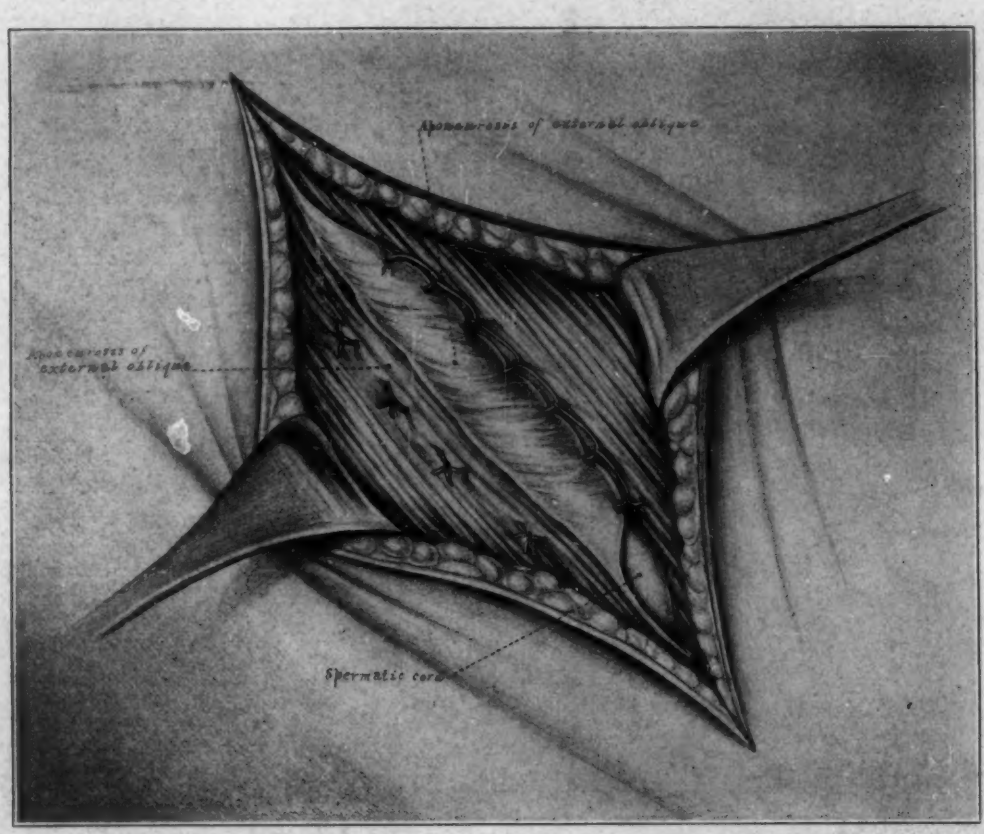

Fig. 15.—Andrews operation completed.

now of the opinion that the sac can be removed in most instances just as thoroughly without sacrificing this vessel. These hernias should all be classed as direct and handled as such. After the sac has been disposed of, the rent in the transversalis fascia should be closed if possible, a continuous suture of chromic gut being utilized for the purpose (Fig. 9). A second retractor is now placed low down under the continuation of the internal oblique and transversalis muscles, and the sharp margin of the rectus muscle located with the finger. The sheath of the rectus is then opened along its anterior border, and the muscle exposed from about the level of the internal ring down to its pubic

attachment (Fig. 9). Three to four sutures of kangaroo tendon are introduced between the outer portion of the rectus muscle and the deepest part of Poupart's ligament. If the transversalis fascia has not been closed satisfactorily as a separate layer, it should be included with these structures. The sutures should be placed from one half to three quarters inch apart and inserted from below up — the lowest one passing from just above the insertion of the rectus muscle to the terminal portion of the ligament (Fig. 10). After they have been properly placed, gentle traction should be made on the sutures drawing muscle and ligament well together, and while thus held by an assistant, they should be tied in the order of their insertion (Fig. 11). The usual Bassini operation

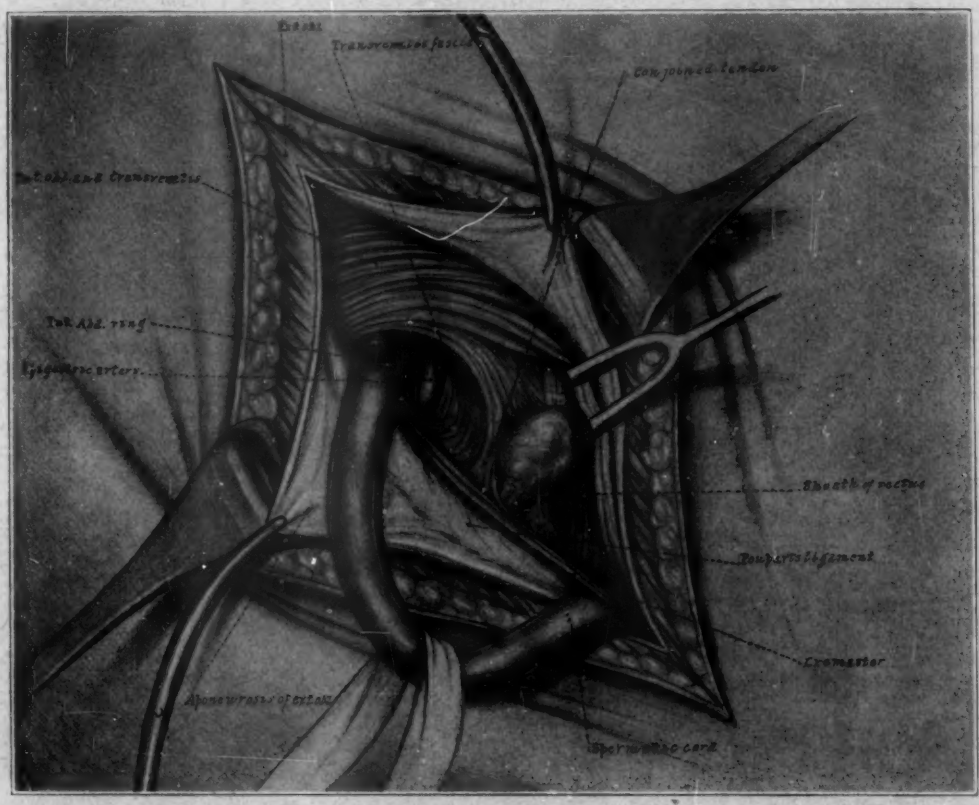

Fig. 16.—Hernia of linea semilunaris.

is now performed from above downward, the sutures picking up a small bite of the rectus muscle and catching Poupart's ligament just superficial to and between those of the first row (Fig. 12). Excessive fat should be removed from the cord, but the veins should not be excised. In closing the external oblique, care should be taken to restore the external ring to as near normal as possible. The hernia of the linea semilunaris in this region is closed by removal of the sac, and the use of one or two mattress sutures placed between the margin of the rectus sheath and the conjoined tendon and transversalis fascia followed by the Bassini or Andrews operation. As these hernias are in close proximity to the bladder, the sac should be dissected with great care.

COMMENT

Complete removal of the sac is the most important step in the operative treatment of any form of hernia, but it is necessary to provide sufficient support at the weakened area in the abdominal wall in order to prevent recurrence. In indirect inguinal hernia, proper use of the internal oblique and transversalis muscles satisfactorily overcomes this weakness; but in the direct type, these muscles alone do not meet the requirements. By making use of the rectus muscle, an additional layer is added to the weakened posterior wall of the canal. It is not asserted that the fibers of this muscle form a true union with Poupart's ligament or that they always remain permanently in the new position, but they do aid greatly in the formation of new connective tissue at a point where every bit of additional support is of value in the prevention of recurrence. By the use of the foregoing method, recurrences in my cases have been reduced more than half, and now that I am selecting the cases for operation with greater care, I believe that the permanent cures will show a still further increase.

Eucouraging, however, as these results may be in some ways, I feel that there is still room for improvement in the operative treatment of direct hernia. With this object in view, my assistant, Dr. R. W. Bolling, and I have recently decided to combine transplantation of the rectus muscle with the Andrews operation instead of the Bassini in the hope that this combination will give even better results (Fig. 13). The mattress sutures are placed as recommended by Andrews for his posterior operation with the addition of a continuous suture between the margin of the external oblique flap and Poupart's ligament (Fig. 14). This stitch of fine gut insures closer contact between these aponeurotic structures. The lower flap of the external oblique muscle is then sutured over the cord in the usual way (Fig. 15). If there seems to be tension in the upper flap of the external oblique muscle, a free liberating incision may be made through the sheath of the rectus well back over the belly of the muscle and parallel with its fibers. It might be said in passing that sutures placed under tension are of little or no value as they soon cut out. Kangaroo tendon or chromic catgut was used for all deep sutures up to the time of changing methods, but we are now trying celluloid linen in one series and absorbable sutures in another.

COMPLICATIONS

Two accidents occurred in this series of cases — both about ten years ago. One was in a recurrent hernia in which the vas was cut as the incision was made through the skin. The cord had been placed superficial to the external oblique aponeurosis at the original operation. In the other, a large hernia with much properitoneal fat, the

bladder was opened, but the injury was recognized and no ill effect followed. This is the only time I have ever seen the bladder opened during an operation for hernia, nor have I ever seen the iliac artery or vein injured in this operation. Hematoma of the cord seldom follows operations for direct hernia, owing to the fact that the sac is rarely adherent to this structure. Postoperative hydrocele is of such rare occurrence after operation for this form of hernia that I would almost be inclined to look on this condition as a coincidence rather than a result. As a matter of fact, the various forms of tumefaction in the scrotum referred to by Seward Erdman [2] as occurring after the hernia operation are rarely seen, provided the cord is managed correctly during the operation, and the scrotum properly supported by a well fitting suspensory afterward. In no instance has atrophy of the testicle been noted in following up these cases. The patient in which the vas was divided was lost track of shortly after operation.

Since 1909, I have operated by the method referred to, that is, rectus transplantation combined with the Bassini operation, on 249 patients with direct hernia. In sixty-nine, the hernia was bilateral, making a total of 318 operations. Ninety patients have been followed for one year or longer, including twenty-three in whom the hernia was double. In this total of 113 operations, there have been six recurrences, or a recurrence of somewhat less than 5.5 per cent. It is suggestive that three of the recurrences followed operation for bilateral hernia performed at one operation.

CONCLUSIONS

1. The patient with a direct inguinal hernia should be carefully studied before recommending operation. If the condition of the lower abdominal muscles is such that a fair chance of obtaining a cure cannot be offered, the question of operation should be deferred for the time being and the patient advised to take systematic exercises for a period of from six months to one year.

2. There is a small but definite group of patients with poorly developed muscles on whom it is not wise to operate for this condition, as recurrence is almost certain to follow.

3. Complete removal of the sac and the use of the rectus muscle in conjunction with one of the recognized operations for indirect inguinal hernia have reduced our percentage of failures in direct hernia more than half.

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2. Erdman, Seward: Ann. Surg. **66**:702 (Dec.) 1917.

A REVIEW OF EIGHT YEARS' EXPERIENCE WITH BRAIN TUMORS*

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In previous papers, I have considered various phases of neurologic surgery. In this paper I shall discuss my series of brain tumors, which number eighty-five. These unquestionably present the most difficult and varied problems which the neurologic surgeon encounters.

In a recent paper read before the Clinical Congress of Surgeons, Cushing said that the time had passed when there is any purpose in speaking of the mortality in brain tumor cases any more than there is in speaking of the mortality in abdominal tumor cases. That such a generalization leads nowhere is also apparent in a study of my cases, and would be most discouraging were we to content ourselves with the bald statement that of the eighty-five patients, we lost twenty-nine, or 35.5 per cent. But when we study these cases from other angles, we find that eighteen of these twenty-nine deaths were in patients suffering with glioma, and that sixty-four, or a little more than 74 per cent., of the patients had tumors other than glioma, and the mortality in these cases was only 17 per cent. There would be other ways of studying these figures, and I doubt not that it might be possible to juggle figures so that I could claim an even lower mortality for certain groups of cases. That, however, is not my purpose. The outstanding fact is that the largest mortality in brain tumor cases occurs in those patients that have gliomas. Let us, therefore, first consider the problem of gliomas.

TYPES OF GLIOMAS

What are the facts about gliomas? Some grow by replacing tissue and others by displacing tissue. Those that do not add to the cranial contents and merely replace tissue do not give rise to any general symptoms of increased pressure, and the only symptoms we observe are focal phenomena, irritative or paralytic in character. The focal symptoms may be the prominent or only features of a case; and though

* Read before the Academy of Medicine, Kansas City, Mo., March 12, 1920.

the tumor may grow to be quite large, it may give no general signs whatever of pressure. This cannot be emphasized too frequently. A diagnosis of brain tumor may be made though there are no general signs of pressure. Because this fact is not recognized, early interference is often not undertaken; but early operation is more important

Fig. 1.—Patient with tumor which was removed four years ago. With the glioma there was a large cyst at least twice as large as the tumor. The only observable symptom the patient now has is a defect in past pointing in one hand.

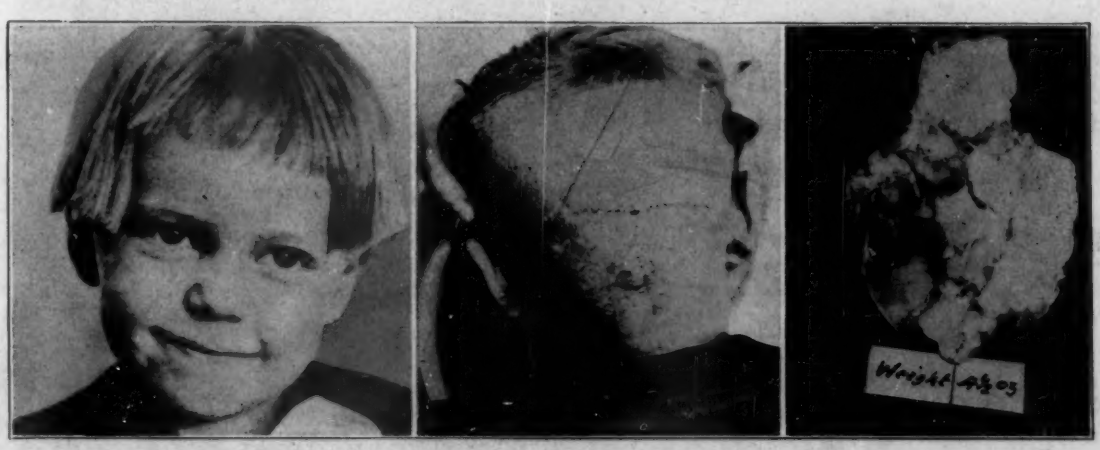

Fig. 2.—Patient with glioma which showed no cystic degeneration.

in dealing with this type of tumor than with any other. Gliomas are frequently spoken of as malignant tumors, but this is, in my opinion, not correct, for one of the chief characteristics of a malignant tumor is the fact that it metastasizes, and this gliomas never do. Infiltration of surrounding tissue can hardly be the criterion of malignancy in judging gliomas on account of the peculiar structure of brain tissue

itself. Infiltration may be used as a criterion of malignancy when the tissue involved has sharp lines of demarcation itself, but the glia reticulum, which is the foundation structure of brain tissue, is itself diffuse and without these lines of demarcation so that infiltration cannot be properly assumed as a test of malignancy in gliomas. If we go beyond the limits of a glioma, we can remove it radically. I have a few cases in my series which bear this out (Figs. 1 and 2).

We have preached and pleaded for years that brain tumor cases must come to operation early, and various periods have been set during which other treatment could be tried. My study of these cases brings out some interesting facts on this very point. The only successful

Fig. 3.—Glioma in which a large vein that ran directly through it had to be ligated. A very marked cerebral edema developed which should have been provided for by a decompression. Eight years ago, when this operation was performed, the importance of adding a decompression operation was not appreciated. This is the type of glioma in which only glia nuclei predominate.

extirpations of gliomas we have had were in patients whose symptoms were present four months or less, though there were several that I lost that I think I could save today that had had the symptoms for a little longer time. Therefore, four weeks should be the longest time to try palliative measures, and using dilatory methods that extend over months is absolutely wrong and unjustifiable. Every brain tumor should be treated on the theory that it may be a glioma, and should

be grouped with the most urgent cases that need hospital treatment. Of the gliomas in this series, 26 per cent. were readily removable, though our successful extirpations constituted only 14 per cent. One patient would have been saved had a donor for transfusion been in readiness, a contingency for which we always provide now when we expect an extensive tumor removal. The other would have been saved had a decompression been combined with the tumor removal to take care of the inevitable edema that takes place in all such cases (Fig. 3).

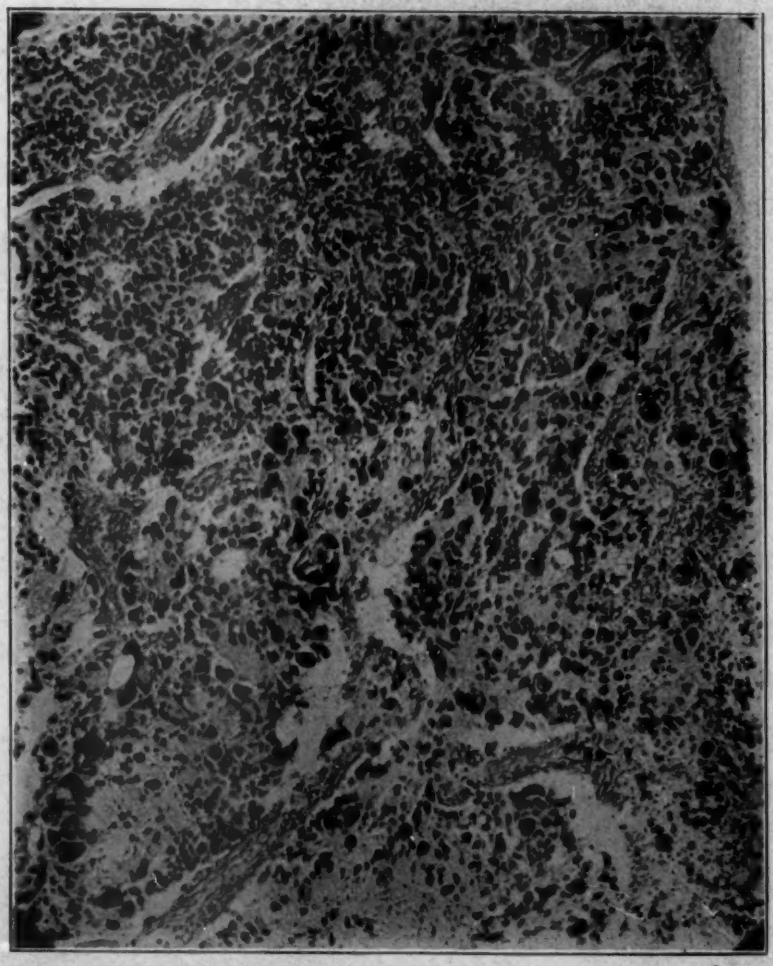

Fig. 4.—Glioma containing various types of cells. Many giant cells present.

Another phase of the question is whether the gross pathology of a glioma gives one any clew as to the type of glioma one is dealing with, and to what extent the character of the glioma influences the prognosis. I have found most useful the classification of gliomas that was employed some years ago by Tooth in his analysis of the cases at the

London Queen's Square Hospital for paralyzed and epileptics. According to this classification, there are three types: First, that in which the glia nuclei predominate. These cases have often been called sarcomas, as the underlying network of glia reticulum has been overlooked (Fig. 3). Second, that in which there are glia cells of varying size. Some of them are giant cells with multiple nuclei and are not unlike

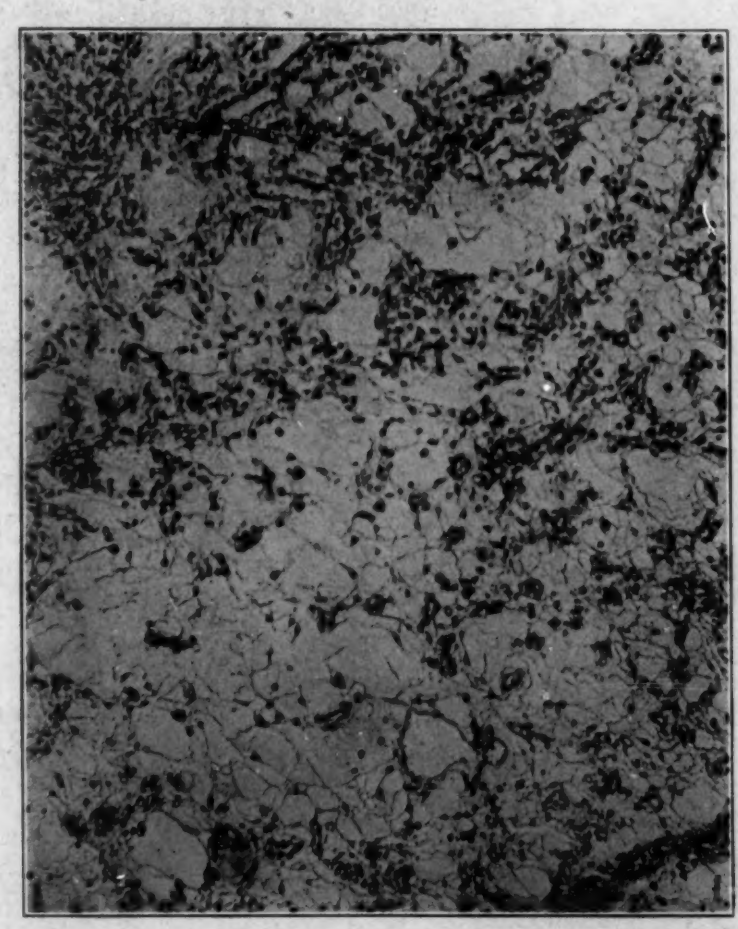

Fig. 5.—Glioma containing few cells and much reticulum.

the giant cells in a giant cell sarcoma (Fig. 4). Third, that in which there are few cells and which is made up mostly of a very loose reticulum (Fig. 5). I doubt whether any one can recognize the type of glioma from the gross appearance, though with a larger experience that may be possible. I have the impression, however, that the last group I mentioned is the most unfavorable, and is the most rapidly growing glioma.

DEFORMITIES AND MORTALITY IN THIS TYPE OF TUMOR

A question that naturally suggests itself is whether the type of operation is responsible for the mortality. This seems to play no rôle, for practically as many patients died after a simple decompression as after an extensive bilateral cerebellar exposure or osteoplastic flap over the cerebral cortex. What, then, are the factors responsible for the deaths and how can they be obviated?

Do gliomas produce conditions in the cranial cavity that other tumors do not produce at all, or not so markedly? In studying the specimens of fatal cases, I have been impressed with the fact that the brains in cases of gliomas are much more deformed than in other types of tumors (Figs. 6 and 7).

Fig. 6.—A glioma which markedly deformed the pons.

Gliomas differ from other tumors in three respects: (1) They are faster growing; (2) they are very soft in consistency, and (3) they are not encapsulated.

Are all or any of these factors responsible for these deformities? A rapidly growing tumor may produce more deformity of a brain than a slowly growing one because the brain is not able to accommodate itself and instead of becoming compressed locally, thus making room for the tumor, it is pushed away *en masse*. Slowly growing encapsulated tumors make room for themselves by causing a local atrophy. That rapidly increasing pressure may produce such deformity

is well illustrated in a traumatic case (Fig. 8). A tumor of soft consistency might also bring this about. Other possible explanations that have been suggested are that the tumor, since it is soft, would far more easily take up fluid from the adjacent brain substance by osmotic action, dehydrate it, and make the normal brain smaller in volume. Then, too, in rapidly growing tumors the blood vessels do not have the well developed elastic layer that normal vessels have and consequently can be more easily compressed, and secondary edema would occur much more readily. Neither of these, however, seems an adequate explanation. The latter fact explains, I believe, why gliomas readily become edematous and take up more room after pressure has been released by a decompression operation; but it does not account for cerebral deformity. I have thought that possibly gliomas not being encapsulated, may create different pressure conditions in the

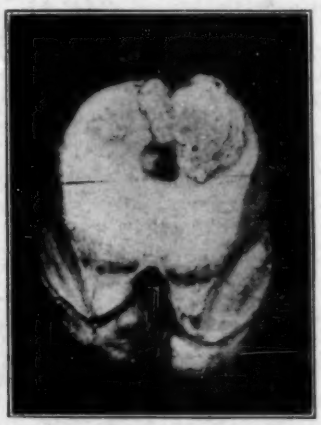

Fig. 7.—A gumma of about the same size and in about the same region as that in Figure 6 which has caused no deformity at all.

cranium than processes that are well encapsulated. Physicists I have consulted have been unable to give me any explanation that would support such an idea. I am, therefore, inclined to explain the deformity that we know occurs by the first of these three factors—the rapid growth.

A very important part of the treatment of gliomas consists in dealing with these deformities. If a tumor is removed in a case in which such a deformity exists, the sudden release of pressure results in the compressed and deformed brain trying to fill up the space, and the great edema that results may throw out of function centers at some distance from the tumor and thus cause the patient's death. Therefore, before removing a tumor we must try to reduce this deformity which can best be done by a decompression operation on the side of

the tumor; for if the decompression should be performed on the side opposite the tumor, the deformity would be increased. This is one of the principal reasons for performing operations in tumor cases in several stages. Thus, in these eighty-five cases we have performed 106 operations. To work in the intracranial cavity while the pressure is markedly increased is an unwise and well nigh impossible procedure. A preliminary decompression helps to reduce the pressure; but in addition to this, the dura if possible should never be opened until the intracranial pressure has been reduced to normal or slightly below normal. This is done most safely by withdrawing the fluid from the

Fig. 8.—Specimen from patient with hemorrhagic leptomeningitis. The compression of the brain was produced by the large collection of fluid, and the sudden release of this fluid caused edema of one cerebral hemisphere.

ventricle, not by lumbar puncture. Even after a bone flap has been turned down, lumbar puncture may result in a dropping down of the cerebellum on the medulla, resulting in the inevitable medullary collapse. Not infrequently the ventricle on the side of the tumor is collapsed, so that I make it a rule to take the fluid from the opposite ventricle. I have no other rule as to the amount of fluid I remove than to reduce the pressure as evidenced by the tenseness of the dura to normal or slightly below normal. I realize that this method is

crude; but until some one makes a tonometer similar to the one used by ophthalmologists to test intra-ocular tension, we must be content with this method. I have performed about 100 ventricle punctures, and have never yet observed any harm resulting from the procedure.

In the removal of a tumor, the surrounding brain tissue should be handled very gently, and the finger should if possible never be used for this purpose. Blunt dissection, I think, is preferable to a knife.

PROCESSES OTHER THAN TRUE BRAIN TUMORS

The other cases in this series include a considerable variety of processes, and the question might well be raised whether it is proper to call them all true tumors. The reason for this is that the preoperative diagnosis in these cases was brain tumor, and that at operation increased pressure was found in those cases in which the tumor was not looked for or not found, or a lesion which acted like a tumor was found, though it might not have been a true neoplasm, for example, a cyst.

This group contained sixty-four cases with eleven deaths, a mortality of 17 per cent. Twelve of these cases were cysts. They were of various kinds. In one or two of them probably there was a glioma underlying the process; but the operation did not reveal the tumor, and unfortunately in neither of these two cases — one patient died two months after operation— were we able to obtain a necropsy. The fluid in both of these cases was brownish, but as it was not gelatinous we could not be positive that we were dealing with a gliomatous cyst. The third patient in this group that died had a huge cyst which had completely replaced the vermis. The patient developed a cerebrospinal fistula about the sixteenth day after operation, and this, I think, must have permitted an infection to get in which led to her death twenty days after the operation. There was no necropsy obtained in this case; but unquestionably the condition was not associated with a glioma, for the cyst contained clear fluid. At that time (1913) I did not understand the pathology of this cyst, but some recent work of Beneke contains the explanation for this and some other cases that I have observed from time to time.

In thinking about and seeing cases of birth hemorrhage, I had believed the majority of them occurred over the cerebral cortex; but Beneke points out from a study of the stillborn that by far the larger number of birth hemorrhages occur in the posterior fossa and are due to rupture of the fibers of the tentorium of the cerebellum. Most of the patients with tentorial hemorrhage die; but undoubtedly some survive, and such a cyst as I found in this case might well have been produced in this way. I should like to point out in passing that some of the patients with spastic paraplegia due to birth injury in which

there are marked ataxic movements and little spasticity may well have had a posterior fossa hemorrhage and either a cyst or adhesions about the foramen magnum producing an obstructive hydrocephalus.

The other cysts were either traumatic in origin, or in one or two instances they were huge porencephalic cavities, a condition which, so far as I know, has never been definitely explained by the pathologist. The usual view is that it is a congenital defect.

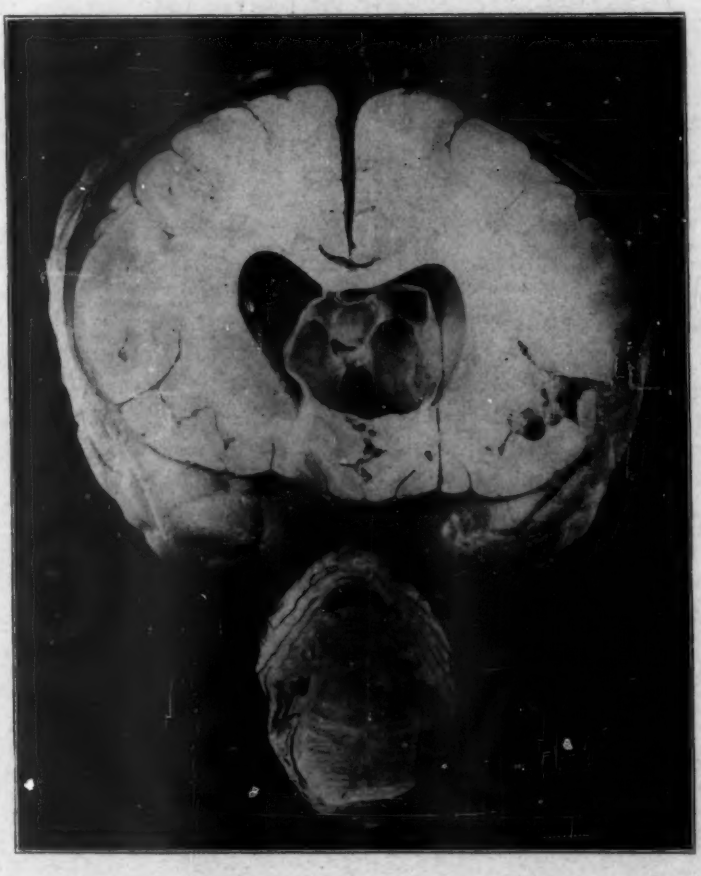

Fig. 9.—Multiple cysts of Taenia solium causing symptoms of brain tumor.

The next large group in this series is composed of thirty cases which we have diagnosed as brain tumors, indeterminate; that is, the patients had symptoms of brain tumor, but decompression operations were performed only to relieve the general pressure symptoms because no focal signs were made out, or explorations were made which did not reveal the pathologic process. Some of these cases will, in course of time, be reclassified and put into other groups when we learn their pathology. In this group there may be cases of so-called pseudo-

tumors; but such a diagnosis should not be made until necropsy has shown the absence of any other pathologic lesion.

An analysis of this group could well be made the subject of a separate study, for the problems it presents in the way of diagnosis are very numerous. One such case that ultimately was taken out of this group may serve as an interesting example. The patient, a butcher, first presented cerebellar symptoms. A cerebellar exploration revealed great pressure but no tumor. He was relieved and went back to work. Some months later, he returned with a new set of symptoms which pointed to the pituitary, and a sella decompression was performed. This relieved him to some extent. Three months later, he suddenly died and necropsy disclosed the cause of death to be a small pontile hemorrhage; but the necropsy in addition revealed multiple cysts of *Taenia solium* (Fig. 9).

This group illustrates very strikingly the fact that palliative procedures often afford a surprising amount of relief and for a considerable time. To prevent a patient's becoming blind and to relieve the headaches are in themselves well worth while, though it may only mean that the patients have relief for a few months or for a year or two.

The other cases in this group comprised a few each of various types, not enough of any one variety to justify any conclusion or deductions in this paper, in which I have attempted to treat of groups rather than individual cases.

RELATIVE PROGNOSIS OF THE TWO GROUPS

In considering collectively the sixty-four cases comprising the second portion of this paper, it is striking to note how very much more favorable these cases were than the first group, and also that many of these patients had had the symptoms for a long time, several years, and nevertheless were relieved. The word "relieved" is used advisedly; for to speak of a cure in the case of a patient suffering from a tumor is always questionable. The length of time that has elapsed since operation and the amount of disability that is present are points that have to be considered in arriving at a proper appraisement of the patient's status when discharged.

We must admit frankly, also, that it is infrequent to have a patient so completely relieved of the symptoms that no trace of the malady remains. This is due to the fact that the cerebral lesion has destroyed or impaired some function, just as disease elsewhere in the body also does; but the impairment after a cerebral lesion may be much more apparent. Occasionally, however, we succeed in restoring a patient so perfectly that only the most careful scrutiny reveals any defect. Such, of course, must be the goal toward which we continue to strive.

AMPUTATION NEUROMAS

THEIR DEVELOPMENT AND PREVENTION

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Odier at the beginning of the nineteenth century first described the enlargements or swellings which develop on the distal end of a proximal segment of a peripheral nerve after partial or complete division. He spoke of these as nerve tumors. Since that time these enlargements, or neuromas, have been frequently studied. Interest in them has often been stimulated by war, for the number of painful stumps following amputations necessitated by mutilating wounds or infections have made a study of neuromas, with a view of determining the factors concerned in neuroma formation and the cause of spontaneous pain after they have developed, imperative.

The histologic descriptions of neuromas differ widely. The variations are easily explained, for when the earlier histologic examinations were made, histologic methods were not refined and specific stains were not employed. With the introduction of the silver method, which permits of clear differentiation of the neuraxes, the descriptions have become more uniform. It is possible to determine now what rôle the different tissues entering into the formation of the nerve play in the development of the neuroma.

Scar tissue has been considered by many as the determining factor in neuroma formation. Senn, in an article published in the *Yale Medical Journal* in 1897, states that it is well known that amputation neuromas will only develop in connection with scar tissue and the irritation incident to the condition producing it, and that every neuroma will be embedded in more or less scar tissue. It is more than probable that the cut ends of the nerve fibers become attached to the scar tissue which acts the part of a foreign substance and excites the active and abnormal proliferation on which depends the formation of the neuroma. Senn quotes thus from an article published by an assistant of Nicoladoni in substantiation of his views:

> The numerical increase in nerve fibers is apparent and not real, for the increase is due to the formation of loops growing out of the elongation of preexisting fibers. With proliferation or growth of these fibers the interstitial connective tissue proliferates under the same influence, the resulting tissue constituting histologically a true neurofibroma.

The importance of scar tissue as a factor in the causation of neuromas has been, as already stated, emphasized by many. The true amputation neuroma forms only on the distal end of the proximal

segment of a divided nerve. The occurrence of these bulbous enlargements only on the distal end of the proximal segment of a divided peripheral nerve and the fact that they are peculiar to nerves suggests that there are certain changes occurring during nerve repair which, when it does not pursue its regular course, ends in the formation of these bulbous enlargements. It will be shown by experiments which will be discussed later that neuromas develop on nerves in the absence of scar tissue or when it is reduced to a minimum and in wounds in which healing by first intention has occurred.

HISTOLOGY OF NEUROMAS

It will not be necessary to review at length the different opinions which have been expressed concerning the histology of neuromas and their significance. It will be interesting to note, however, a few of these.

Langstaff found in neuromas no evidence of the normal structure of a nerve. Probst and Smith regarded the neuroma as composed of fibrous tissue without any nerve elements, while Legoust and Guerin thought the simple neuroma to be caused by a hypertrophy of the connective tissue elements of the nerve.

Chauvel made microscopic examinations of thirty-two neuromas. He found nerve fibers in these. The fibers increased in number from the periphery to the central part of the bulbous enlargement. He also found nerve fibers passing beyond the enlargement to end in the connective tissue lying beyond the cut end of the nerve. He believes that the neuroma is caused by the growth of the endoneurium and perineurium, and that although nerve fibers are found passing through the enlargement, they do not undergo any change. Virchow in 1858 described the neuroma as consisting of a thick network of axis cylinders between which were scattered small amounts of connective tissue. He found the nerve fibers arranged in bundles or funiculi of varying but considerable size. These were surrounded by perineurium which separated them sharply from one another.

Kölliker believed that the neuromas which develop in clean wounds and in wounds in which there are no foreign bodies are new growths which are composed almost entirely of nerve tissue. Another group which develop in infected amputation wounds he regarded as inflammatory in character and as an expression of regenerative energy. More or less newly formed fibers are always found in these enlargements.

Gottsacker thought that the neuroma developed as the result of hyperplasia of the elements entering into the formation of the nerve. The enlargement forms not as the result of the rolling up of nerve fibers, but as the direct result of increase in numbers. Some of the

neurofibrillae grow beyond the cut surface of the nerve and form a tangle of nerve filaments in the connective tissue beyond it. The non-medullated fibers in the neuroma are but early stages of the medullated.

Klebs regarded the neuroma as indicative of an attempt to restore normal conditions. He believed that the growth of the neuroma ceased with the development of myelin sheaths, but that there was a possibility that growth might continue even after the sheaths developed.

Schuh believed that the scar tissue which develops at the end of a nerve after division gives rise to a certain resistance to the growing or regenerating neuraxes which causes them to leave the straight course which they usually pursue to zigzag in all possible directions; some of them turning back on themselves within their sheaths. The neuroma consists of scar tissue and neurofibrillae which are irregularly interlaced, some of which have more or less completely formed medullary sheaths. The entire process is to be regarded as an attempt at regeneration which has been modified or thwarted by scar tissue. Some of the neuraxes are turned back on themselves, while others interlace or intertwine in the scar tissue in their attempts to pass through it.

Cruveilhier believed that the bulb formed to protect the nerve end, while Billroth thought that the neuroma represented the tissue growth associated with an attempt of the constituents of the central end of the divided nerve to reach the part of the nerve lying opposite and to complete regeneration. Ziegler thought that the neuroma developed as the result of a growth exceeding physiologic limits, a useless, tumor-like formation resulting.

Cone has recently drawn attention to the predominance of nerve fibers in neuromas. According to him, microscopic examination demonstrates that the homogeneous mass consists of interlacing funiculi of young nerves, the funiculi varying from 10 to 50 microns in diameter. Sometimes larger ones are found among these. When one sees larger fibers running parallel and bound together in bundles, they usually belong to the original trunk from which the others spread. As a rule, these are found on one side and away from the tip of the bulb. Sometimes, however, these bundles may be found at the very tip, for the trunk not infrequently coils around as a whole before sprouting at the end.

Small interlacing funiculi are the most characteristic feature of the neuroma, but not infrequently single tendrils growing wild in the surrounding tissues are found. They are varicose, bulbed at the end; they branch frequently and course in a spiral manner. The supporting surrounding tissue is, as a rule, cellular, vascular, wavy connective tissue, not loose areolar tissue. It is rather compact, more so than is usually the case with cellular connective tissue. Cone believes that

many of the spindle-shaped nuclei are derived from the proliferating sheath of Schwann cells. A large number of nuclei are always found among the fibers. Sometimes they are staff-shaped; sometimes they are fusiform. The shape seems to depend somewhat on the stage of regeneration. Cone has frequently seen these so numerous that the section resembled that of a leiomyoma.

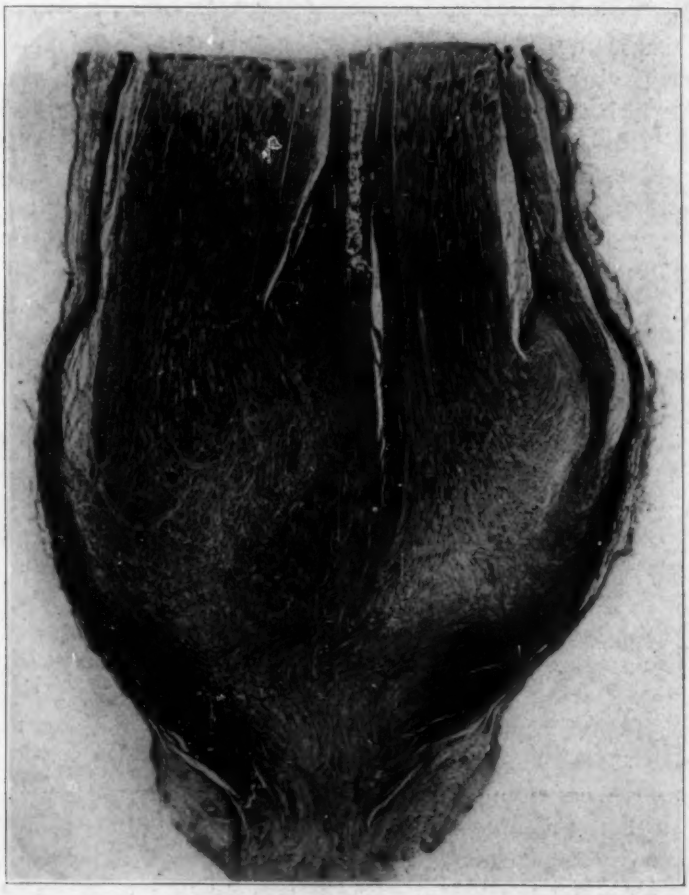

Fig 1.—Longitudinal section through typical neuroma showing relation of epineurium and connective or scar tissue cap to the end of the nerve. The straight longitudinal neuraxes may be seen in the proximal part of the neuroma just before they reach scar tissue in the center of the neuroma. Nerve was divided transversely thirty-one days before this specimen was removed.

It can be seen that the opinions which have been expressed concerning the histology of the neuroma vary, and that its significance has been variously interpreted.

Suppuration undoubtedly contributes to their formation as it increases the amount of scar tissue, but even at the present time when sepsis is relatively uncommon neuromas form although many are not associated with spontaneous pain.

REPORT OF EXPERIMENTAL WORK

The experimental work, which we report here, had as its first object the determination of the factors which caused neuroma formation and as its second object the prevention of the neuroma.

The operations were performed under strict aseptic precautions and the dissections were made along intermuscular septums to avoid hemorrhage. Thus the two factors, suppuration and hemorrhage, to the consequences of which so much importance has been attached in the causation of neuromas, were eliminated. When the nerve was exposed, the sciatic being used in all cases, it was divided transversely by sharp knife or scissors.

In all cases, even when perfect aseptic healing occurred, a neuroma developed. The neuroma was well formed by the nineteenth day after division. The bulbs may vary somewhat in shape, but they tend to become oval or spherical. If the bulb rests on bone or tendon or some resistant tissue, the part of the bulb resting there may be somewhat flattened, while the other parts increase in size. The increase in size takes place where there is the least resistance.

One of us (Lewis) has seen one instance of a divided nerve in a war wound in which the divided ends had been driven into the bone where no neuroma formed, and he believes that in this instance the pressure of the surrounding bone prevented bulb formation, which occurs with such frequency that it might almost be regarded as normal.

Figures 1 and 2 represent the appearance of neuromas after longitudinal section. The neuroma represented in Figure 3 has been cut somewhat obliquely. It, however, did not present the symmetrical enlargement presented by the neuromas represented in Figures 1 and 2.

The gross general characteristics of a neuroma are well represented in Figures 1 and 2. Evidently after a transverse section of a nerve, the funiculi retract within the epineurium. The epineurium contracts down over the cut end of the nerve, but does not completely cover it, for the cut end is covered by a connective tissue cap which becomes continuous on all sides with the epineurium. In Figure 1, this cap seems to be placed on top of the epineurium. This connective tissue cap occurs quite regularly in neuromas. It indicates apparently the site of a blood clot which forms over the end of the nerve after division. This becomes transformed into scar tissue by invasion of connective tissue from tissues surrounding the nerve end, from the endoneurium, perineurium and epineurium. This connective or scar tissue cap does

not block completely developing neuraxes, for in a number of specimens neuraxes which have penetrated this cap are found in the connective tissue lying beyond the nerve.

In a microscopic examination of the neuroma, the most striking thing is the spirals which were apparently first described by Perroncito in his experiments dealing with nerve regeneration. These will be described first, for they seem to indicate the factor which is most to be emphasized in neuroma formation.

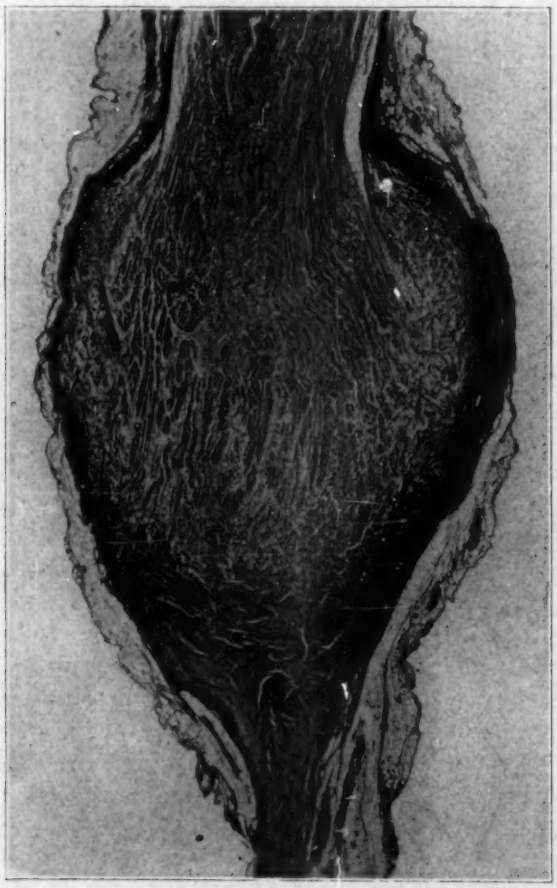

Fig. 2.—Typical neuroma, presenting pyramidal shaped cap and showing relation of epineurium. Parallel bundles of neuraxes can be seen passing relatively low down in the outer part of the neuroma.

A high power representation of a spiral is seen in Figure 5. The growing neuraxes of the regenerating nerve are blocked by connective or scar tissue. They are unable to penetrate this, and they then spiral back within their own sheath, using the original neuraxis of the sheath

as the axis around which they spiral. Developing from the branching neuraxis of this spiral are several end disks. These disks merely represent exaggerated forms of the smaller end bulbs which are observed in nerves undergoing normal regenerative processes. A number of neurofibrillae may develop from each of these disks, or the disk may undergo a degenerative change. The center of a disk may dis-

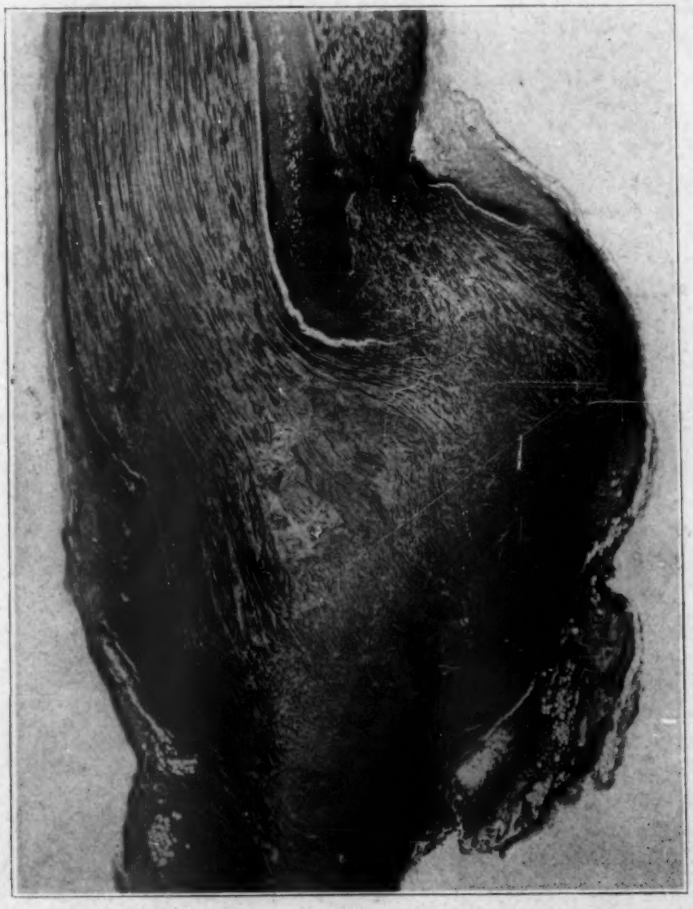

Fig. 3.—Oblique section of a neuroma which did not have the typical spherical shape. The shape of a neuroma may be modified by pressure. When lying on bone or tendon, it may be flattened while the side enlarges where the resistance is less.

appear, leaving a nerve ring, which was also described by Perroncito, although he does not seem to have thought of the possibility of nerve ring formation as a result of degeneration of the center of a nerve disk. As a spiral enlarges, it may rupture its neurilemmal sheath. It then

comes to lie directly in contact with the connective tissue of the neuroma. These spirals we believe to be one of the characteristics of an amputation neuroma in the earlier stages of its formation. They indicate well the growth energy of neurofibrillae stimulated to reproductive activity by division of a nerve.

Figure 4 represents the number of spirals which may be observed in a neuroma. They have no constant position. The spiral represented in Figure 5 was found at the periphery of a neuroma, while the spirals

Fig. 4.—Group of spirals found in the proximal zone of a neuroma, just at the point where the straight longitudinal neuraxes first meet the connective tissue of the neuroma.

represented in Figure 4 were found in the center, in its proximal part where many of the fibers still retained their straight course and were not broken up and dispersed by scar tissue.

Figure 6 represents the dispersion of neuraxes which occurs when the regenerating fibers reach the scar tissue. The neuraxes, which have a fairly straight course, are found in the proximal part of the neuroma. As they approach the neuroma, they become broken up and dispersed. In this instance, which is apparently quite accidental, these fibers bend in toward the center of the neuroma. Some small funiculi

may be seen, but usually the neurofibrillae are so broken up that a funicular arrangement is no longer preserved and the single fibers have an irregular zigzagging course through the scar tissue.

Figure 7 is a section through the center of a neuroma. It indicates the irregular distribution of neuraxes in the scar tissue of the neuroma. In this section, there is, however, an attempt at the formation of

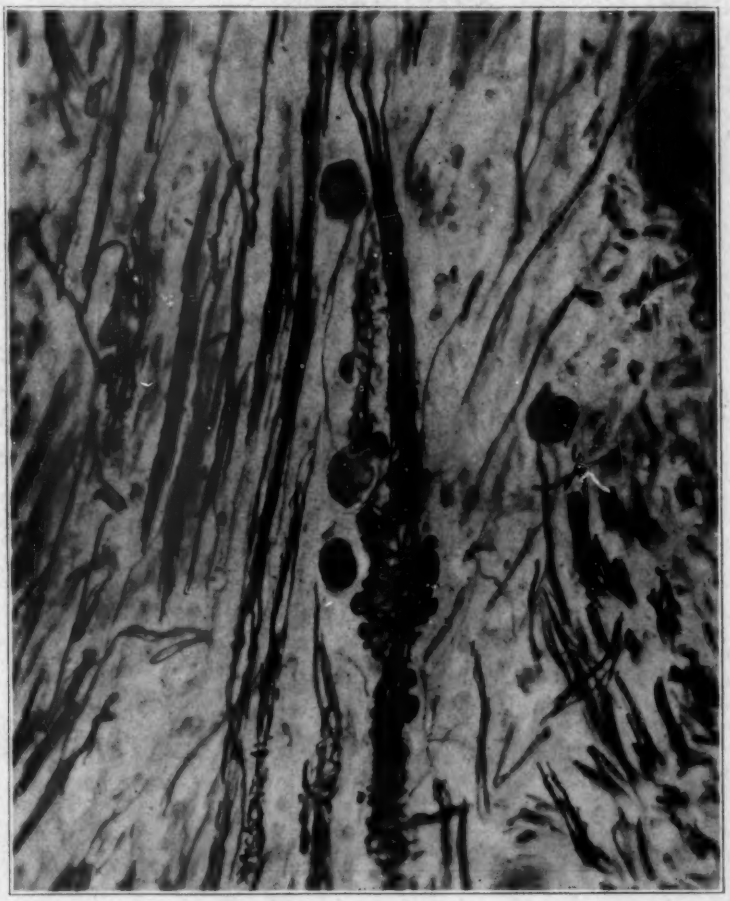

Fig. 5.—High power of a spiral showing neuraxes spiralling back within the neurilemmal sheaths and several large end disks. As the spiral enlarges, it may break through the neurilemmal sheath and come to lie in the connective tissue. The center of these disks may disappear to form a nerve ring.

funiculi. There is no constant distribution of the different elements as has already been emphasized. A zonal arrangement in the neuroma has, however, been described by some.

In all sections, numerous end bulbs and disks indicative of marked attempts at regeneration may be seen.

The peculiarities of the connective tissue of the neuroma have been noted by many. Figure 8 represents this tissue. It is rather loose and wavy and contains peculiarly shaped cells and fibers which appear to be swollen. It is rather a young connective tissue and remains so for some time. It is quite probable that the developing

Fig. 6.—Proximal zone of a neuroma. Parallel neuraxes may be seen passing into the beginning of the neuroma. Several small end bulbs and disks may be seen on the neuraxes. The neuraxes become broken up and dispersed and irregularly distributed through the scar tissue.

neuraxes during their regenerative activity stimulate this connective tissue to an excessive growth which continues for some time. In our attempts at prevention of neuroma formation, as will be shown later, it was thought that if the neuraxes could be prevented from regenerating until the tissue which developed in the cut end of the nerve had

become more adult connective or scar tissue, the bulbous enlargement, which is formed largely by developing neuraxes, but also by connective tissue, could be prevented. This loose, vascular tissue is formed by the endoneurium and perineurium, and encloses proliferating cells of the neurilemmal sheaths. It is practically impossible, however, to

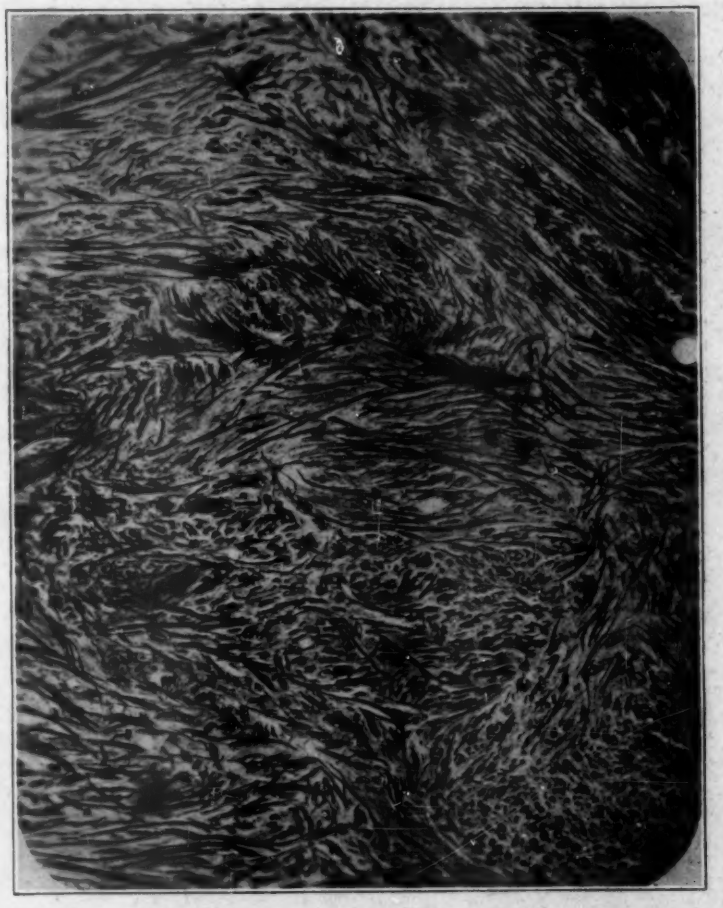

Fig. 7.—The arrangement of the neuraxes in the center of the neuroma.

differentiate the sheath cells from the other cells which form constituent parts of the nerve.

In the older neuromas, as shown in Figure 14, this scar tissue becomes more compact and sclerotic, and in the older neuromas it forms relatively heavy septums which surround and separate neighboring funiculi.

Corner, in discussing neuroma formation, states that divided nerve fibers first degenerate and afterward regenerate, undergoing two

changes, while the connective tissue (endoneurium, perineurium and epineurium) commences at once to repair, undergoing but one change, and that as a result the connective tissue of the nerve gets a considerable regenerative start as compared with the neuraxes. Consequently, in the early stages, according to Corner, the end bulb of a divided nerve consists very largely of fibrous tissue. Into this tissue, the nerve fibers grow. The central part of the end bulb is formed

Fig. 8.—The character and arrangement of the connective tissue in a neuroma.

from the repairing inner coats of the nerve (the endoneurium and perineurium). Its outer and circumferential parts are largely formed from the outer coat (epineurium). This connective tissue bulb has partly ceased to contract by the time the nerve fibers grow into it by reason of its early start, and it offers a substantial buffer to the regenerating fibers.

The regenerative changes in neuraxes occur much more rapidly than Corner states. Within six hours after division of a nerve, there are definite evidences of regenerative activity on the part of divided neuraxes. Some of these may be abortive, but some are definitive. The changes in the neuraxes and connective tissue occur and progress simultaneously, and it seems certain that the developing neuraxes stimulate the connective tissue to increased and continued growth.

A neuroma indicates an attempt, which is thwarted or blocked by scar tissue, on the part of the neuraxes of a divided nerve to seek the

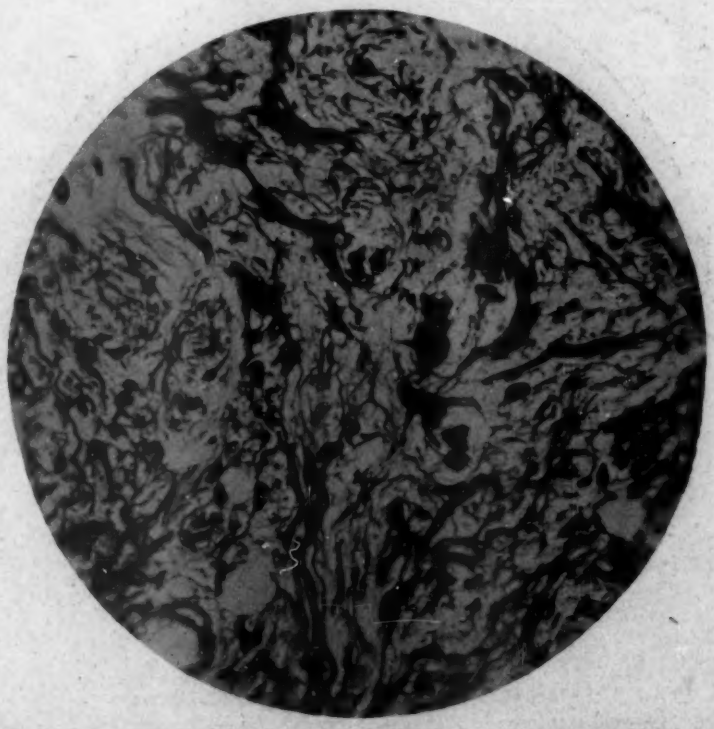

Fig. 9.—The character and arrangement of the connective tissue in a neuroma.

distal segment and thus complete nerve repair. These regenerating neuraxes then either form spirals or irregularly distributed and dispersed fibers in the bulb. These in their growth stimulate the connective tissue to increased and continued growth.

Any procedure which is employed with the intention of preventing neuroma formation must be directed against the neuraxes rather than against the connective tissue of the end of the nerve.

The following procedure has been employed by us to prevent neuroma formation. After the division, the trunk of the nerve is

injected with absolute alcohol from three-fourths to 1 inch above the plane of section. Enough alcohol is injected to make the nerve appear a dull white, resembling quite a great deal cooked egg albumin. The following experiments are cited to show the effect.

RABBIT 24.—Large, full grown; 11 days.

March 1, 1918: Left sciatic nerve exposed; large nerve; absolute alcohol injected at several different points. Approximately 2.5 cm. of the nerve was well injected. Nerve cut distal to the points of injection and about 1 cm. resected.

Fig. 10.—Effects of absolute alcohol injection on the neuraxes. Finely granular material remains of degenerated neuraxes. Neurilemmal sheaths, many of which remain, are filled with granular masses and globules of fat.

March 12: Rabbit killed. Sciatic nerve exposed. Distal end of proximal segment of nerve surrounded by small amount of pus. Nerve end slightly enlarged, and a light yellow. Hemorrhage into nerve trunks, extending for a distance of about 3 cm. from end. Central segment removed and fixed in neutral liquor formaldehydi. Tissue stained by the Bielschowsky silver method.

Microscopic Findings: In several series of longitudinal sections of successive levels of the distal end of the proximal segment, the neuraxes in the injected areas are broken up into short irregular segments. The myelin of the fibers is present in the form of a granular detritus and smaller and larger globules. The neurilemmal sheaths appear well preserved. Here and there

irregularly formed cellular elements are found within the neurilemmal sheaths, the histogenesis of which cannot be clearly determined.

RABBIT 40.—Full grown; 18 days.

March 5, 1918: Left sciatic nerve exposed. Absolute alcohol injected at several points into the internal popliteal divisions. Quite a little alcohol escaped into the wound. The nerve was cut distal to the points of injection and resected. Wound closed.

March 23: Rabbit killed. Wound well healed. On exposing the sciatic nerve, no material increase of connective tissue about the nerve was noted. Distal end of the proximal segment tapers to a fine point, which is slightly

Fig. 11.—Section of specimen, ninety days after injection. Degenerated neuraxes and myelin sheaths may be seen in lower part of the field. Straight longitudinal regenerating neuraxes may be seen in upper part. No evidences of spiral formation or end disks seen in this section.

adherent to the underlying muscle. About 2.5 cm. of the proximal segment is a light yellow. Proximal sciatic segment removed and fixed in neutral liquor formaldehydi for Bielschowsky silver staining.

Microscopic Findings: In two series of longitudinal sections of successive levels of the distal end of the proximal segment it can be clearly determined that both of the divisions of the sciatic have been well injected, the alcohol evidently having passed into the main trunk of the nerve. Almost all of the neuraxes have been broken up into short segments and granules. The myelin has been broken up into a granular detritus. The neurilemmal sheaths

are easily made out. In these many spindle-shaped enlargements are found at irregular intervals. Small nuclei, the origin of which is doubtful, are scattered throughout the granular myelin detritus. The fibrous tissue sheaths of the distal end of the proximal sciatic segment appear thickened. Fibrous tissue is found at the cut end of the nerve.

RABBIT 14.—Full grown; 20 days.

Feb. 28, 1918: Left sciatic nerve exposed and injected with absolute

Fig. 12.—Section of distal end of proximal segment of a rabbit's sciatic nerve, ninety days after injection with absolute alcohol. Tapering end of nerve without any evidence of neuroma formation may be noted. The ends of nerves treated in this way often present in the earlier stages a peculiar yellowish white appearance due to the degenerated myelin.

alcohol, several point injections being made. Very little alcohol escaped into the wound. Nerve cut distal to the points of injection and 1 cm. resected. Wound closed.

March 18: Rabbit found dead. Wound well healed. On exposing the sciatic, the distal end of the proximal segment is found to taper to a fine line

which is adherent to the underlying muscle. A small blood clot surrounds the distal end of the proximal segment. Proximal segment removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin and picrofuchsin.

Microscopic Findings: In several series of longitudinal sections made at successive levels the structural appearance is such that the sections would not be recognized as sections of peripheral nerve tissue. Endoneural connective tissue strands and neurilemmal sheaths are the only parts which may be

Fig. 13.—A few neuraxes in injected part of nerve.

recognized in the larger internal popliteal bundle. The neuraxes have disappeared completely. The myelin has been broken up into a granular detritus or appears as inclusions in large vesicular cells having very small nuclei. In the external popliteal nerve, not so fully injected, some normal neuraxes are to be found. In others, degenerative changes resembling those occurring in a nerve after division are found. The neurilemmal sheaths of both the internal and external bundles present a structural appearance not unlike that of a normal nerve.

Rabbit 28.—Small, half grown; 21 days.

March 1, 1918: Left sciatic nerve exposed and injected with absolute alcohol. Successful injection, hardly any alcohol escaping. Nerve resected distal to the point of injection. Wound closed.

March 22: Rabbit found dead in the morning. Seemed well nourished. Wound healed well. On exposing the left sciatic nerve, it was found to be slightly adherent to the muscle bed. The distal end of the proximal segment tapers for a distance of 1.5 cm. to form a fine strand. It is a light yellow. Distal end of proximal segment removed and fixed in neutral liquor formaldehydi. Sections stained with iron-hematoxylin and picrofuchsin.

Fig. 14.—Old neuroma with relatively dense sclerotic scar tissue surrounding funiculi. The fibers forming these funiculi have for the most part acquired their medullary sheaths.

Microscopic Findings: In several series of longitudinal sections, including the area of alcohol injection, the perineural sheaths of the funiculi appear slightly thickened. The neurilemmal sheaths of the old fibers are present only in part. In the areas in which they have disappeared and in some of the distended sheaths are found large vesicular cells, notably compressed, which have granular and globular inclusions. The cells have small nuclei. Such cells are less numerous in the distal part of the proximal segment. The nerve is consequently reduced in size.

Rabbit 11.—Full grown; 24 days.

Feb. 26, 1918: Left sciatic nerve exposed and injected with absolute alcohol. Resected distal to point of injection.

March 22: Rabbit found dead in the morning. Seemed well nourished. Wound well healed. The nerve when exposed was found but slightly adherent to the underlying muscle. Distal end of the proximal segment presents tapering end. The proximal part of the nerve was removed and fixed in neutral liquor formaldehydi. Sections stained with iron-hematoxylin and picrofuchsin.

Microscopic Findings: In a series of longitudinal sections of the distal end of the proximal segment, including the part injected with absolute alcohol and 2 cm. proximal to it. Practically all the neurilemmal sheaths are preserved. Many of the old neurilemmal sheaths are greatly distended. Here and there, they have disappeared. In such areas and within certain of the neurilemmal sheaths, large vesicular cells with small nuclei are observed. Both of the main bundles are equally affected.

RABBIT 1.—Large, full grown; 36 days.

Feb. 18, 1918: Left sciatic nerve exposed and raised from its bed for several centimeters. Lifted on hook and injected with absolute alcohol. Nerve well injected presenting milky white appearance. Resected distal to point of injection.

March 26: Rabbit died during morning; still warm when found. Much emaciated. Abscesses filled with cheesy material found in different parts of body. Wound well healed. On exposing the sciatic it was found that the external popliteal division of the nerve had not been injected and cut. The internal popliteal division was found to have a tapering end. Nerve fixed in neutral liquor formaldehydi. Bielschowsky silver staining, good differentiation of neuraxes.

Microscopic Findings: It is evident from a study of several longitudinal sections that the internal popliteal was insufficiently injected, for a large number of the fibers are not affected by the alcohol, showing normal nerve fibers. In the part injected, the neuraxes and myelin sheaths have disappeared and are replaced by granular detritus and large vesicular cells with protoplasmic inclusions. Perineural connective tissue not materially thickened.

RABBIT 21.—Full grown; 36 days.

Feb. 28, 1918: Left sciatic exposed and injected with absolute alcohol. Injected in two places 8 mm. apart. Nerve resected distal to points of injection.

April 5: Rabbit found dead in the morning; emaciated; wound well healed. On exposing the nerve a discoloration about the distal end of proximal segment (probably due to hemorrhage) was noted. The distal end of the proximal segment tapers to nearly a point and is a light yellow. About 1.5 cm. proximal to the distal end, the nerve presents a normal appearance. Nerve removed and fixed in liquor formaldehydi. Sections stained in iron-hematoxylin and picrofuchsin.

Microscopic Findings: In three series of longitudinal sections taken at successive levels, including about 3 cm. of the distal end of the proximal stump, the following observations were made. Approximately 2 cm. proximal to the place of injection, normal nerve tissue is reached. Distal thereto, in progressive degrees, neuraxes and myelin are replaced by granular detritus, globules and phagocytic cells, in part within neurilemmal sheaths, in part in areas in which the neurilemmal sheaths have disappeared, only strands of endoneural connective tissue remaining. Down-growing nerve fibers, in part with very thin myelin sheaths, can be traced from the central undegenerated portion into the degenerated area. These fibers are found singly or in small bundles; have a very regular course, in the main parallel to the long axis

of the nerve, and reach to within 1 cm. of the distal end of the proximal stump. Here and there strands of nucleated bands of syncytial protoplasm are noted in the degenerated portion of the nerve.

Rabbit 2.—Large, full grown; 49 days.

Feb. 18, 1918: Right sciatic exposed; partly freed and injected with absolute alcohol; cut distal to points of injection and resected. Wound closed.

March 18: Wound completely healed; hair growing over shaved area.

April 8: Found dead in the morning. On exposing nerve, it was found that the external popliteal bundle was cut, but that internal was intact. External popliteal presents slight enlargement of distal end of the proximal stump; end tapers to fine strand and is a light yellow. Nerve removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin.

Microscopic Findings: Only cut external popliteal sectioned. It is evident from a study of a series of longitudinal sections that this branch was but partly injected, for disintegration of neuraxes and myelin sheaths is observed in but a small area. The remainder of the stump resembles closely in structure that of amputation neuroma, with proliferation of connective tissue and down-growing neuraxes. This experiment cannot be regarded as successful.

Rabbit 43.—Half grown; 52 days.

March 5, 1918: Left sciatic exposed and injected with absolute alcohol; one injection. Quite a little alcohol escaped into wound. Nerve cut and resected. Wound closed.

April 25: Killed. Rabbit in good condition. On exposing nerve, it was found to present normal appearance to about 2.5 cm. from distal end of the central stump. Distal end shows a slight spindle-shaped enlargement centralward, then tapers to a fine strand. Streaks of yellow white, parallel to long axis observed. The distal end of the central stump removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained.

Microscopic Findings: In three series of longitudinal sections, taken at different levels, it may be observed that in the distal part of the proximal stump to the extent of about 2 cm., the neuraxes and myelin and in part the neurilemmal sheaths of the nerves have been replaced by granular and globular detritus and vesicular cells, arranged in columns or groups, separated by strands of endoneural connective tissue and neurilemma remains. Single neuraxes or small groups of such, growing from the central undegenerated portion of the nerve, can be traced into degenerated area. These neuraxes have a regular course, in the main parallel to the long axis of the nerve. Nucleated protoplasmic strands accompany these neuraxes. In the distalmost part of the central stump as yet no new neuraxes are found; from this part also the granular detritus and vesicular cells have disappeared.

Rabbit 22.—Full grown; 56 days.

Feb. 28, 1918: Left sciatic exposed and injected with absolute alcohol; well injected. Nerve cut distal to field of injection and resected. Wound closed.

April 25: Killed. Rabbit in good condition; slight neurotrophic ulcer, left foot. Wound well healed. On exposing nerve, it is found that it presents a normal appearance to about 1.5 cm. from distal end of the proximal stump, which presents only very slight enlargement, is a yellow white and tapers to fine strand, which seems continuous with surrounding connective tissue. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Successful silver differentiation obtained.

Microscopic Findings: In three series of longitudinal sections taken at successive levels, it may be observed that numerous new neuraxes growing from the central undegenerated portion of the nerve have grown distally into the portion injected with absolute alcohol. These neuraxes course singly or in small bundles, having in the main a longitudinal course, the small bundles of neuraxes showing here and there an interchange of fibers. Between these neuraxes are found columns or areas of granular detritus and vesicular cells. The down-growing neuraxes have practically reached the distal end of the central stump. There is observed no tangling or crisscrossing of neuraxes as seen in a neuroma; nor is there such an intergrowth of neuraxes and connective tissue as is observed at the end of a neuroma.

RABBIT 41.—Large, full grown; 58 days.

March 5, 1918: Left sciatic exposed and internal and external popliteal bundles injected separately; the former is injected in two places; well injected. Nerve cut distal to point of injection and 1 cm. resected. Wound closed.

May 3: Rabbit found dead in the morning. Neurotrophic changes, left heel; popliteal lymph gland enlarged. On exposing the nerve, it is found that the central stump tapers to fine strand, and is a light yellow. About 2 cm. proximal to distal end of central stump nerve presents normal appearance, with funiculi distinct. Nerve removed and fixed in Fleming chrom-osmic-acetic solution. Sections stained in safranin and licht grün.

Microscopic Findings: In three series of longitudinal sections taken at successive levels, it may be observed, beginning with the most distally placed series, that the neuraxes and myelin of the nerve fibers of both of the main funiculi have entirely disappeared. Fine strands of endoneural connective tissue and neurilemmal sheaths remain forming a very open meshed network, surrounding areas of granular and globular detritus, through which are scattered small round or oval nuclei. In the series of the next higher level, the same general structure is found for the greater part of the section. In the more central portion of the sections, small strands of syncytial nucleated bands of protoplasm are observed, which become more numerous in the centrally placed of the three series. These nucleated protoplasmic bands have grown into the degenerated portion of the nerve from the central undegenerated portion.

RABBIT 38.—Nearly full grown; 63 days.

March 5, 1918: Left sciatic exposed; quite a little bleeding; controlled. Two injections of absolute alcohol made; both bundles injected. Nerve cut and 5 mm. resected. Wound closed.

May 13: Rabbit found dead in the morning; in fairly good condition. On exposing the nerve, distal end of proximal stump is found tapering to fine strand slightly adherent to muscle bed. The distal end for a distance of about 2 cm. is a light yellow; central to this nerve has normal appearance. Nerve removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin and picrofuchsin.

Microscopic Findings: In several series of longitudinal sections taken at successive levels, it is observed that in the distal end of the central stump, in the area of the alcohol injection, neuraxes and myelin of the nerve fibers have entirely disappeared, fine strands of endoneural connective tissue and remnants of neurilemmal sheaths remaining. This portion of the nerve consists almost wholly of granular and globular detritus, surrounded by the perineural sheaths. More proximalward in the series of sections, nucleated

protoplasmic bands growing distally from the undegenerated central nerve are to be observed; to one side, near the perineural sheath, these protoplasmic bands extend distally to near the distal end of the central stump.

RABBIT 18.—Full grown; 65 days.

Feb. 27, 1918: Left sciatic exposed; large vein cut; clamped. Absolute alcohol injected and nerve cut just distal to injected field and resected. Wound closed.

May 5: Found dead in the morning. Protocol incomplete, simple statement, "No neuroma."

RABBIT 10.—Full grown; 71 days.

Feb. 26, 1918: Left sciatic exposed and injected with absolute alcohol. Nerve cut distal to field of injection; 1 cm. resected. Wound closed.

May 8: Killed. Rabbit not in good condition; emaciated; "fungus" ears. On exposing the left sciatic the proximal stump is found to end in a fine tapering strand, not especially adherent to the muscle bed, of light yellow. About 2 cm. proximal to the distal end, nerve presents the appearance of normal nerve. The nerve removed and fixed in ammoniated alcohol for pyridin silver stainings. Very good differential silver staining obtained.

Microscopic Findings: From the microscopic appearances presented in the several series of longitudinal sections taken at successive levels, it is evident that the injection of alcohol was not wholly successful in this experiment. Numerous neuraxes may be traced from the central portion of the nerve, toward the end of the proximal stump, numerous large end disks are found at various levels. Especially to one side of the nerve, and about 2 mm. from its distal end, numerous complex spirals of neuraxes are to be observed. At the distal end of the proximal stump, crossing and recrossing of neuraxes are observed, though there is not observed that intergrowth of neuraxes and connective tissue such as is generally seen in a neuroma. In the entire series of sections, few remains of myelin and neuraxes of the old nerve fibers are observed. The conclusion seems warranted that at the time of operation the nerve trunk was partially injected with absolute alcohol and that after section of the nerve a partial neuroma developed.

RABBIT 32.—Full grown; 80 days.

March 4, 1918: Left sciatic exposed. Several injections of absolute alcohol made, spaced at intervals of about 5 mm. Well injected. Nerve resected 1.3 cm. just distal to field of injection. Wound closed.

May 23: Killed. Rabbit in good condition; severe neurotrophic changes, left hind foot. On exposing left sciatic, it was found to present a normal appearance to within 2 cm. of distal end of central stump. The end presents first a slight enlargement then tapers to a fine strand only loosely adherent to the surrounding connective tissue. Distal nerve segment completely degenerated. Central sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained.

Microscopic Findings: Three series of longitudinal sections and one series of cross sections were made. Sections were made of approximately 3 cm. of the distal end of the proximal sciatic stump. The most centrally placed sections include a portion of the normal nerve. Numerous down-growing neuraxes may be traced from this portion of the nerve into that portion immediately influenced by the absolute alcohol. In the latter portion areas and columns of globular and granular detritus are found, coursing between which there may be observed smaller and larger bundles of neuraxes, which

have in the main a regular course, with here and there an interchange of fibers. These down-growing neuraxes may be traced to the distal end of the proximal stump, but present no tangling or intertwining as observed in a neuroma. The perineural sheath surrounds these down-growing neuraxes.

RABBIT 26.—Full grown; 83 days.

March 1, 1918: Left sciatic exposed and injected with absolute alcohol. Well injected. Nerve cut distal to field of injection and 8 mm. resected. Wound closed.

May 23: Killed. Rabbit in good condition. On exposing the left sciatic, it was found to present normal appearance to within 2 cm. of distal end of central stump. Distal end of central stump presents slight enlargement, then tapers to fine strand, adherent to underlying muscle. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings: In two series of longitudinal sections in which approximately 4 cm. of nerve is sectioned, it is observed that numerous neuraxes growing distalward from the central uninjured portion of the nerve extend into the portion affected by the absolute alcohol. These neuraxes are enclosed within the thickened perineural and epineural sheaths and have in the main a longitudinal course, except those found in close proximity to the fibrous sheaths, many of them cross and recross and intertwine on the inner surface of the perineural sheath. These down-growing neuraxes can be traced to the attenuated end of the proximal stump. The remains of the fibers affected by the absolute alcohol are found in areas of granular detritus, interspersed with large vesicular cells, and fat cells, between which course the neuraxes.

RABBIT 29.—Full grown; 83 days.

March 1, 1918: Left sciatic exposed and injected with absolute alcohol; well injected. Nerve cut distal to field of injection and resected. Wound closed.

May 23: Rabbit found dead in the morning. Left femur found broken; apparently some days before death. On exposing the sciatic, tissues about nerve found much congested and containing extravasated blood; owing to fracture. The distal end of the central sciatic found to taper to fine strand; relations not clear owing to extravasated blood. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings: In two series of longitudinal sections including approximately 4 cm. of the distal end of the proximal stump, large number of down-growing neuraxes may be traced from the uninjured central portion of the nerve to its distal end. These neuraxes are enclosed in the thickened fibrous tissue sheaths of the nerve and have in the main a regular course. Within the area injected with absolute alcohol, a few columns and areas of granular detritus, certain large vesicular cells and many fat cells are found. Such columns and areas are separated by bundles of down-growing neuraxes, a few of which cross such fields either as single fibers or as small bundles of such.

RABBIT 17.—Nearly full grown; 84 days.

Feb. 27, 1918: Left sciatic exposed and injected with absolute alcohol. First injection not successful; nerve slightly torn. Second attempt at a higher level, was successful; well injected. Nerve cut and resected. Wound closed.

May 22: Rabbit found dead in the morning; seemed in good condition; severe neurotrophic changes, left hind foot. On exposing the left sciatic, the distal end of the proximal stump is found to taper to a fine strand; adherent to the underlying muscle. Several delicate nerve bundles appear to extend on the muscle bed for a distance of about 1 cm. beyond the cut end of the nerve. No evidence of a neuroma noted. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained. A portion of the nerve removed in this experiment was lost; the portion at hand represents the most distal portion of the central stump for the length of a little over 1 cm.

Microscopic Findings: In a series of longitudinal sections, small bundles of fine neuraxes, enclosed within the thickened fibrous sheath are observed. These bundles of neuraxes are found separated by areas of granular detritus and fat cells.

Rabbit 42.—Half grown; 84 days.

March 5, 1918: Left sciatic exposed and injected with absolute alcohol; larger bundle in two stages; smaller bundle, one injection. Well injected. Nerve cut and 1 cm. resected. Wound closed.

May 29: Rabbit found dead in the morning. Protocol incomplete. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings: In three series of longitudinal and cross sections in which approximately 4 cm. of nerve was cut, central neuraxes are found passing distalward through the area injected with absolute alcohol and have reached the distal end of the proximal stump, and as scattered neuraxes or as small bundles of such can be traced into the connective tissue overlying the muscle bed for a distance of about 1 cm. beyond the cut end of the nerve. In the main, these neuraxes have a very regular longitudinal course. Very little detritus, the remains of the injured nerve fibers are found in the area injected with absolute alcohol.

Rabbit 8.—Full grown; 90 days.

Feb. 23, 1918: Left sciatic exposed and injected with absolute alcohol; well injected. Nerve cut just distal to injection; 1 cm. resected. Wound closed.

May 23: Killed. Rabbit very much emaciated; severe neurotrophic changes of foot, two toes missing; large ulcer on heel. On exposing the sciatic, this is found of normal appearance to about 1.5 cm. from end of proximal stump. End of stump presents slight enlargement then tapers to a fine strand. This nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Faint, but differential neuraxes staining obtained.

Microscopic Findings: In three series of longitudinal and one of cross sections, taking in a little over 4 cm. of the distal end of the nerve, the following may be observed: Neuraxes in large numbers can be traced from the proximal practically uninjured portion of the nerve, through the area affected by the alcohol to the distal end of the proximal stump. In a series of cross sections, taken about 2 cm. above the point of puncture for alcohol injection, the funicular structure of the nerve is not lost; the perineural sheaths are distinctly thickened. Within the funiculi, numerous neuraxes seen in cross section, four to ten within one neurilemmal sheath. Not all of the funiculi are equally affected. In the more distal portion of the nerve, in two series of longitudinal sections, numerous neuraxes, having in the main a longitudinal course, and arranged in larger or smaller bundles, and separated

by elongated areas and columns of granular detritus, vesicular cells and fat cells are to be observed, enclosed within the thickened fibrous sheaths.

RABBIT 37.—Full grown; 93 days.

March 5, 1918: Left sciatic exposed and injected with absolute alcohol; both bundles well injected. Nerve cut about 5 mm. distal to place of injection and 1 cm. resected. A small amount of alcohol escaped into the wound. Wound closed.

June 6: Killed. Rabbit in fair condition; neurotrophic ulcer on left heel. On exposing the sciatic nerve it is found to present normal appearance to near end of distal stump which tapers to a fine strand. Nerve removed and fixed in Fleming's chrom-osmic-acetic mixture. Sections stained with safranin and licht grün. In several series of cross and longitudinal sections made from the distal 4 cm. of the proximal stump, the following observations are made: In the series of longitudinal sections small bundles composed of nucleated protoplasmic bands and fine myelinated nerve fibers may be traced from the central normal portion of the nerve to the end of the distal stump. Between these there are found broader or narrower columns composed, in the main, of large vesicular cells with small nuclei, having globular and granular protoplasmic inclusions. These cells would appear to have phagocytized the remains of the nerve fibers affected by the absolute alcohol. The fibrous sheaths of the distal end of the central stump are found materially thickened. In the distal 1.5 cm. the funicular structure of the nerve trunk is lost.

RABBIT 34.—Full grown; 94 days.

March 4, 1918: The left sciatic exposed and injected with absolute alcohol; well injected. Nerve cut 5 mm. distal to place of injection and 1 cm. resected. Wound closed.

June 5: Killed. Much emaciated; severe neurotrophic ulcer, left heel. On exposing the left sciatic nerve it is found normal to within 1.5 cm. of end of the proximal stump. It presents a slight enlargement then tapers to fine strand; adherent to the underlying muscles. Nerve removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin and picro-fuchsin. Tissue not well embedded, sections torn.

Microscopic Findings: In the sections remaining it can be determined that nucleated protoplasmic bands extend from the proximal undegenerated portion of the nerve to the distal end of the proximal stump. These bands of nucleated protoplasm may be regarded as non-myelinated fibers. Between such bands or bundles are found columns or long spindle shaped areas of large closely arranged vesicular cells with globular or granular inclusions.

RABBIT 39.—Small rabbit, not full grown; 95 days.

March 5, 1918: Left sciatic exposed; free venous bleeding. Absolute alcohol injected; large bundle in several places; smaller bundle, one injection. Well injected. A small amount of alcohol escaped into wound. Wound closed.

June 8: Rabbit found dead in the morning. On exposing the left sciatic, it presents a normal appearance to within a short distance of the distal end of the proximal stump which tapers to a fine strand. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Silver differentiation is not successful.

Microscopic Findings: Several series of longitudinal sections, though not showing differentiation of neuraxes, are sufficiently stained to admit of the interpretation that there was no neuroma formation. The arrangement of the connective tissue warrants this conclusion.

Rabbit 27.—Full grown; 97 days.

March 1, 1918: Left sciatic exposed and injected with absolute alcohol. On first attempt, movement of animal prevented successful injection; on second trial successful injection was made. Nerve cut distal to point of injection and resected.

June 6: Killed. Rabbit in good condition. On exposing the left sciatic nerve it presents normal appearance to near distal end of the proximal stump which appears to end in fine tapering strand. The relations of distal end of proximal stump is not clearly made out owing to presence of dense cicatricial tissue at end of the fine tapering strand. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Fairly good silver differentiation obtained; sheath nuclei as well as neuraxes stained.

Microscopic Findings: Several series of longitudinal sections made. In these, it is possible to trace numerous neuraxes from the more centrally placed sections, through the field affected by the alcohol injection to the distal end of the proximal stump. At the distal end of the proximal stump the neuraxes were found to cross and recross, especially those found in close relation to the outer fibrous sheath. In the more central portion, the neuraxes present a more regular longitudinal course. In this portion of the nerve, between small bundles of neuraxes, large spindle-shaped areas composed of vesicular cells and granular detritus are to be found. In relation with the distal end of the proximal stump, there was noted at the time the nerve was removed a small irregular mass about 5 mm. in diameter which appeared to consist of dense fibrous tissue. In sections, this mass was found to contain a nucleus of osseous tissue surrounded by dense fibrous tissue. In this fibrous layer, mainly to one side, several small bundles of neuraxes were found. A study of this series of sections suggests imperfect alcohol injection and as a result partial neuroma formation, with proliferation of fibrous tissue consequent to escape of alcohol into the wound.

Rabbit 15.—Full grown; 102 days.

Feb. 26, 1918: Left sciatic exposed and injected with absolute alcohol; nerve cut distal to injection and 1 cm. resected. Wound closed.

June 8: Killed. Animal not in good condition; severe neurotrophic ulcer on left heel; popliteal lymph gland greatly enlarged. On exposing the left sciatic, the central stump is found tapering to fine strand; distal end a light yellow. Connective tissue in proximal part of popliteal space quite dense. Proximal sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained; especially in more central portion of nerve.

Microscopic Findings: Two series of longitudinal sections including the 2 cm. of the distal end of the central stump made. In the more distally placed series, within the thickened fibrous sheath, a granular detritus and vesicular cells occupy nearly the entire area. No down-growing neuraxes appear to have reached this portion of the proximal stump. In the more centrally placed series, numerous new neuraxes are found. Those more axially placed have a regular course; those more peripherally placed criss-cross on the inner surface of the fibrous tissue but do not present the intergrowth of fibrous tissue and neuraxes as noted at the distal end of a neuroma.

Rabbit 3.—Large, full grown; 108 days.

Feb. 18, 1918: Left sciatic exposed and injected with absolute alcohol. Nerve cut about 5 mm. distal to place of injection; not resected. Wound closed.

June 6: Killed. Left hind foot, slight neurotrophic changes on heel. On

exposing the sciatic, it is found that the external popliteal was not cut, and probably not injected. Internal popliteal central stump presents a tapering end. Some delicate fine strands seem to extend beyond the cut end; on cutting these "fibers," no twitching of calf muscles observed. The nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings: Section of the noncut and noninjected external popliteal made with the cut and injected internal popliteal, cut together in series of longitudinal sections. In the sections, the external popliteal presents the appearance of a normal nerve; here and there a few degenerated fibers are noted. In the distal end of proximal stump of the internal popliteal, central down-growing neuraxes can be traced to the distal end, having in the main a regular longitudinal course, and separated into smaller and larger bundles by long spindle-shaped areas, occupied by granular detritus and large vesicular cells. A few neuraxes can be traced into the connective tissue surrounding the distal end of the central stump of the internal popliteal.

RABBIT 25.—Half-grown rabbit; 150 days.

March 1, 1918: Left sciatic exposed and injected with absolute alcohol. Well injected; practically no alcohol escaped to the wound. Sciatic cut 5 mm. distal to place of injection and 1 cm. resected. Wound closed.

July 30: Killed. Rabbit not in good condition. On exposing the left sciatic, the proximal stump is found to end in a fine tapering strand. No bulb. No nerve fibers could be traced beyond the cut end of the nerve. Proximal part of sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained. During embedding the end of the central sciatic stump became bent, so that it was not possible to cut longitudinal sections including the entire length of the piece.

Microscopic Findings: It is evident from a study of the entire series, that down-growing neuraxes coming from the central uninjected portion of the nerve, have passed through the area injected with absolute alcohol and have reached the distal end of the central sciatic stump. These neuraxes have in the main a longitudinal course. Toward the distal end, some crisscrossing of neuraxes is observed; not to the extent found in a neuroma, and such crisscrossing of neuraxes as is observed occurs within the fibrous tissue sheath and mainly on its inner surface.

RABBIT 23.—Nearly full grown; 157 days.

March 1, 1918: Left sciatic exposed and injected with absolute alcohol. Well injected. A small quantity of alcohol escaped into the wound. Nerve cut just distal to place of injection and resected. Wound closed.

August 5: Killed. Rabbit in good condition; foot missing; stump completely healed. On exposing the sciatic the central stump is found to end in fine tapering strand from the distal end of which a fine filament can be traced toward the distal sciatic stump, but does not reach it. Calf and foot flexor muscles completely degenerated. Central sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Not wholly successful differentiation obtained; patchy.

Microscopic Findings: In a fairly complete series of longitudinal sections, taking in the distal 2 cm. of the central sciatic stump, it may be observed that numerous neuraxes, both myelinated and nonmyelinated grow distal through the field of alcohol injection to the extreme distal end of the central stump. Here the connective tissue sheath of the nerve is found very materially thick-

ened, the connective tissue extending into the interior of the nerve end and separating the nerves into small intertwining bundles. More centrally the neuraxes have a more regular longitudinal course, except those found in close relation to the fibrous tissue sheath which course along the inner surface of the sheath without definite arrangement. The structural appearances presented are not those of a neuroma.

COMMENT

The microscopic findings in the distal end of the proximal segment 157 days after alcohol injection are interesting and instructive. By this time numerous neuraxes, both myelinated and nonmyelinated, have passed through the injected part of the nerve to the extreme distal end of the proximal segment. The connective tissue sheath of the nerve is very materially thickened at this point. It extends into the interior of the nerve and separates it into small intertwining bundles. More centrally the neuraxes have a more regular longitudinal course, except those in close relation to the fibrous sheath which course along the inner surface of the sheath without definite arrangement. The structural appearances presented are not those of a neuroma.

These findings are in marked contrast to those noted after operations — recognized surgical procedures — which are performed on the end of the nerve. These operations are the so-called swing door and the crush and tie. We shall quote but two typical examples of these.

Serial sections of this specimen removed two weeks after the swing door operation revealed fairly dense fibrous tissue over the end of the nerve. Distinct neuroma structure is found in the distal end of the proximal segment. At the end of the nerve, just proximal to the fibrous cap, many interlacing newly-formed neuraxes are found in the fibrous tissue. Some of the developing neuraxes are growing into the connective tissue distal to the end of the proximal segment. Many spirals are found at all levels in the series in the part undergoing neuroma formation.

Four weeks after the "swing door," or reversed V, operation, the typical neuroma structure is found. The pyramidal fibrous cap, spirals with interlacing neuraxes and much fibrous tissue are observed. Small bundles of neuraxes with a more regular course are found distal to the area in which the interlacing neuraxes are so numerous. The large number of end disks indicate actively proliferating fibers. There are a good many spirals. These are mostly grouped in several areas.

Four weeks after the crush and tie operation, a distinct neuroma picture is found. The distal end of the proximal segment has a relatively long connective tissue cap, which is pyramidal in shape. The newly formed neuraxes have grown into this long connective tissue

cap. In the region just proximal to this scar tissue there is a marked interlacing of new-formed neuraxes in the fibrous tissue. Many spirals are found in the various fields.

These two operations, which are recommended and employed in clinical surgery, do not prevent neuroma formation. While the neuroma seems to form a little more slowly after the crush and tie operation, it is well formed even after this operation at the end of four weeks.

Even as early as one week after these operations there are distinct evidences of neuroma formation indicated by the development of end disks and spirals which indicate a connective or scar tissue block.

An objection has been raised against the injection of alcohol with the view of preventing neuroma formation. It has been claimed that the alcohol may escape into the surrounding tissues and increase the amount of scar tissue. The surrounding tissues may be easily protected from the alcohol, little, if any, of which escapes if the injection is carefully made. We have observed no marked increase in the amount of scar tissue after its use, and have never observed the formation of a neuroma at the site of injection.

CONCLUSIONS

1. A neuroma indicates an attempt which is thwarted or blocked by scar tissue on the part of the neuraxes of a divided nerve to seek the distal segment and thus complete nerve repair.

2. When blocked the regenerating neuraxes form spirals and end disks, and become irregularly dispersed throughout the connective tissue of the bulb.

3. The regenerating neuraxes react on the connective tissue elements of the bulb, which as a consequence increase in number and maintain their embryonal characteristics longer than is normally the case.

4. The "swing door," or reversed V, operation and crush and tie operation do not prevent neuroma formation.

5. Any method to be successful must be directed against the neuraxes.

6. Absolute alcohol injected into the nerve some distance (from three-fourths to 1 inch) above the plane of section is more successful in preventing neuroma formation than any of the other methods ordinarily employed.

POSTOPERATIVE PULMONARY COMPLICATIONS*

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INTRODUCTION: Importance of subject. Apparent increase in incidence due to better records.

REVIEW OF LITERATURE: Dearth of American and English studies. Statistical tables. Irritation vs. embolism as contributing causes. The rôle of the anesthetic.

PRESENTATION OF MATERIAL: Fifty-five complications, eleven deaths in 1,562 operations. Division into groups. Discussion of groups.

GENERAL DISCUSSION: General factors, age, incidence by seasons, relation to kind of anesthesia. The part chilling, trauma, general condition, anesthesia, preexisting pulmonary disease and sepsis play. Discussion of the mechanism of embolism.

SUMMARY AND CONCLUSIONS: Embolism the chief factor. Prophylaxis by selection of cases, reduction of sepsis and trauma and careful anesthesia.

INTRODUCTION

In the last twenty years with the rapid development of surgery, its spread to ever widening fields and the brilliancy of many of its therapeutic results, much of the wholesome respect for the dangers involved in even a simple operation, which lay so heavy on our forebears, has disappeared. There seems to be an increasing tendency toward surgical therapeusis which now and then leads even the wisest and most experienced surgeons to operate without sufficiently deliberate and careful study. The confessions of the late Maurice Richardson [1] regarding this tendency serve to indicate some lamentable mistakes that ensue, and a study such as the present one points out additional dangers that are just as serious.

It is only in the last few years that the increasing and careful analysis of end-results has brought home again the very certain dangers that accompany all surgical interventions. The medical student is likely to think that with the operation the major part of the treatment ends, but the experienced surgeon realizes that then the difficulties and dangers often commence. Those few surgeons who have deliberately submitted their results to searching public and private scrutiny have convincingly shown that an improvement in results and technic and a steady decrease in postoperative difficulties is an inevit-

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1. Richardson: Boston M. & S. J. **159**:711-716, 752-756, 791-795, 1908.

able consequence. The lessons such analyses have pointed out have always made for progress. Surgeons must frequently balance their accounts if they are to find the small mistakes. Bad results are overlooked or forgotten when such studies are not made, and yet the seriousness of such complications as this study presents cannot be overestimated. There can be no greater calamity than to have an apparently healthy patient succumb after a relatively simple operation.

A previous study in this field by one of us in collaboration with J. J. Morton [2] made it evident that the risks involved in even simple operations were sufficient to cause hesitation, and gave us a desire to find a means for doing away with such risks. There are many dangers in surgery, some immediate, some coincident with the operation, some that arise during the convalescence. The immediate dangers concern technic; the late are more obscure, less spectacular and often chronic, so that less attention has been paid to them. Yet they are by no means unimportant, and, indeed, at times are the cause of death. Of these dangers, postoperative pulmonary disorders should occupy a relatively prominent position, since they are by no means infrequent, often they are most alarming, and at times they are fatal. Our first study in 1916 at the Massachusetts General Hospital was so instructive that we were anxious to repeat it in another institution, to prove our conceptions and if possible to establish further methods of prophylaxis.

There have been from time to time careful studies of this group of cases, and with each successive study the proportion of complications has reached a higher percentage. This is the result not of an increasing incidence, but of more careful study. Whipple,[3] in his second study in this field, which he confines to the pneumonia group alone, reported that at the Presbyterian Hospital, New York, in 1898, an analysis of these complications by Schultze [4] gave 0.38 per cent. (twenty-two pneumonias in 5,724 anesthesias), whereas in 1913-1914 (Whipple [5]) the figure was 2.2 per cent. (42 pneumonias in 1,902 anesthesias), and in 1915-1916 (Whipple [3]) the figure was 2.6 per cent. (ninety-seven cases in 3,719 anesthesias). Our own studies show a postoperative pulmonary complication of 1.86 per cent. in our first paper, and of 3.52 per cent. in this study. Our figures are for total pulmonary complications, Whipple's for pneumonia only. For pneumonia alone our figure reaches 1.6 per cent. The increasing percentage

2. Cutler, E. C., and Morton, J. J.: Surg., Gynec. & Obst. **25**:621 (Dec.) 1917.

3. Whipple A. O.: Surg., Gynec. & Obst. **26**:29 (Jan.) 1918.

4. Schultze: Med. and Surg. Reports, Presbyterian Hospital, New York, January, 1898.

5. Whipple, A. O.: Med. Rec. **89**:581, 1916.

must be well understood or one would deduce an increasing amount of disability. A comparison of the mortality figures brings the real situation to light; in our first paper of 1915-1919, the mortality percentage of morbidity was 50.7; in this study, 1919, it is 20, a very creditable improvement. Even so, the figures, untranslated, are misleading. The material available for study in this report was far more accurate and full, anesthesia charts accompanied all histories, and the preoperative and postoperative findings were more elaborately recorded. We were able, therefore, to assemble a proportionately far larger number of cases since the minor pleurisy and bronchitis cases were all carefully described. Even so, the morbidity and mortality figures are sufficient to cause concern.

We have again taken the whole field of postoperative pulmonary complications rather than a single group, partly because the groups are closely allied, and the study of one group helps in a realization of the etiologic factors in the others; but chiefly because the lesson is more sharply indicated by the exposition of this very similarity of etiology and, therefore, similarity of prevention. Not only the nature of all the complications from anatomic, therapeutic and prophylactic phases, groups them into a single category; but the reason for their occurrence is frequently, even in different groups, through the same mechanism.

A study of the reports made in this field both abroad and in America will convince all that the anesthetic is not the chief factor. Ether pneumonia is, therefore, a very misleading term. There is little doubt that the irritation caused by the anesthetic plays some part, but never the major part.

Our first study led us to lay most stress on the preoperative condition, especially on a preoperative pulmonary lesion, also on the amount of infection present and the proximity of the operative field to the lungs. The present study, which is based on a far more reliable mass of material, although emphasizing many of the deductions in our previous paper, seems to point out that the chief factor is embolism, a finding in agreement with much of the work of previous investigators. The importance of preexisting sepsis is thus seen in a new light, and as will be pointed out later in this study our conclusions are supported by more certain facts. Again, we would emphasize that the anesthetic is not the chief factor; and certainly all surgeons have seen numerous badly administered anesthesias, with blue, "wet" patients, coughing or even vomiting during the period of anesthesia, and yet noticed that no postoperative pulmonary complication has ensued. Indeed, it is the very safety of the anesthesia which has led many astray, since the attribution of the postoperative pulmonary disabilities to such an

evident etiology would seem entirely natural. Again, it is no uncommon thing for a surgeon to remove the appendix, on a mistaken diagnosis, from a patient with unrecognized pneumonia and see absolutely no deleterious effects from the anesthesia. Lastly, the incidence of such a complication under local anesthesia is often very high. Henle,[6] for example, reports more complications with local than after any one of the general anesthetics.

This study was undertaken in an effort to improve the methods and results in this hospital, and it brought to light, to our surprise a larger number of untoward results than we had suspected. And yet, the mortality figures for pneumonia (0.51 per cent.) are comparable to the lowest figures reported from other clinics with the exception of the Mayo Clinic report for 1913,[7] when they reported no deaths, an isolated and inexplicable fact. We have arbitrarily studied the cases submitted to operation in a single year, 1919. During that period there were 2,032 surgical admissions; 1,929 of these were submitted to some sort of intervention in the operating room. Of these, however, only 1,562 were actually submitted to surgical operative procedures under an anesthetic. The cystoscopies, dressings, plaster casts and allied procedures are not included in the 1,562 cases used as the basis for this study. Of these 1,562 patients, fifty-five (3.52 per cent.) developed a definite postoperative pulmonary complication which we have divided into the following groups: lobar pneumonia, bronchopneumonia, bronchitis, pleurisy, empyema, lung abscess, pulmonary embolism and cases showing an exacerbation of a preexisting tuberculous condition after operation. Of these fifty-five patients, eleven died, a mortality percentage of 0.70 for the total number of postoperative complications, and a mortality percentage of the morbidity of 20.0. This is a relatively low figure in comparison to other statistics from general surgical clinics.

It is essential, in order to use statistics, that all conditions be the same; but in medicine this is almost impossible, as no two clinics treat the same type of patient. Thus, we think it unfair to compare our figures with those from clinics where a minimum septic and traumatic work is done and where the clientele is to a large extent drawn either from the country folk or from patients from a distance, which at once eliminates the serious acute surgical emergencies. Any patient who can travel from 200 to 1,000 miles by train must at least be a fairly good risk. The larger number of our patients are drawn from a large city and have neither hereditary nor environmental advantages

6. Henle: Verhandl. d. deutsch. Gesellsch. f. Chir. **30**:240, 1901.

7. Beckman, E. H.: Collected Papers Mayo Clinic, Philadelphia, W. B. Saunders Company, 1913, p. 776.

and are to a considerable extent emergency or traumatic cases. Also, we have taken the whole field of postoperative pulmonary complications, so that only such studies as the previous communication from the Massachusetts General Hospital [2] and Armstrong's [8] from the Montreal General Hospital are suitable for comparison. Our pneumonia figures, however, can be compared to the very numerous contributions in this single field.

We are strongly of the opinion that the anesthetic is never the primary and sole cause of the ensuing complication, and invite a careful study of our cases with this point in view. A study of the preoperative risk chiefly in regard to sepsis, preexisting pathologic condition of the lung or general debility, old age or poor circulation will reveal many important factors. Operative trauma, the position of the wound as regards mobility of the part, the position of the patient on the table, and the anesthesia will now and then rise in their importance in relation to the resulting pulmonary disability.

REVIEW OF THE LITERATURE

Unfortunately, this subject has not until recently received much attention in American and English medical literature, although many workers in German clinics, more than a decade ago, discussed the subject thoroughly, notably, Ranzi,[9] Otte,[10] Laewen,[11] Bibergeil,[12] Pfannensteil,[13] Kroenlein,[14] Henle,[6] Mikulicz,[15] von Lichtenberg,[16] Czerny [17] and Kelling.[18] Just why such an important field has been neglected one cannot say, since it is one of the fields in which the great calamities of surgery occur. It is especially difficult to find studies covering the whole field of postoperative complications, although there exist many studies in the various groups of such complications, particularly studies on postoperative pneumonia.

Table 1 shows an average morbidity of 2.12 per cent. with a mortality percentage of morbidity of 25.2, including the Mayo figures for 1913, when there were no deaths reported. Since the deaths

8. Armstrong: Brit. M. J. **1**:1141, 1906.
9. Ranzi: Arch. f. klin. Chir. **87**:380, 1908.
10. Otte: München. med. Wchnschr. **54**:2473, 1907.
11. Laewen: Zentralbl. f. Chir. **4**:96, 1907; Beitr. z. klin. Chir. **50**:2, 1906.
12. Bibergeil: Arch. f. klin. Chir. **78**:339, 1905.
13. Pfannensteil: Zentralbl. f. Gynäk., 1903, No. 1.
14. Kroenlein: Verhandl. d. deutsch. Gesellsch. f. Chir. **34**:131, 1905.
15. Mikulicz: Verhandl. d. deutsch. Gesellsch. f. Chir. **30**:560, 1901.
16. Von Lichtenberg, A.: München. med. Wchnschr. **53**:2286, 1906; Centralbl. f. d. Grenzgeb. d. Med. u. Chir. **11**:129, 1908.
17. Czerny: Verhandl. d. deutsch. Gesellsch. f. Chir. **34**:109, 1905.
18. Kelling: Verhandl. d. deutsch. Gesellsch. f. Chir. **34**:136, 1905.

occur almost entirely in the pneumonia and pulmonary embolism groups, it is natural that more interest should be displayed in such studies, and we find many and excellent discussions, particularly of the pneumonia group. The total statistics, however, are impressive and would seem to indicate that approximately one patient in every fifty operated on will develop a lung complication, and one in every 185 will die from some such complication.

TABLE 1.—General Surgery — All Lung Complications

Clinic	Author	Reference	No. of Cases	Pulmonary Morbidity		Pulmonary Mortality		Mortality % of Morbidity
				No.	Per Cent.	No.	Per Cent.	
Mayo*	Beckman	Collected Papers Mayo Clinic, 1910, p. 594	3,657	41	1.12	9	0.24	21.9
Mayo*	Beckman	Collected Papers Mayo Clinic, 1912, p. 738	5,835	92	1.57	6	0.10	6.5
Mayo	Beckman	Collected Papers Mayo Clinic, 1913, p. 776	6,825	87	1.27	0	0.00	0.0
Von Eiselsberg	Ranzi	Arch. f. klin. Chir. **87**: 380, 1908	6,871	263	3.8	†	†	†
Montreal General Hospital	Armstrong	Brit. M. J. **1**: 1141, 1906	2,500	55	2.2	32	1.28	58.1
Massachusetts General Hospital	Cutler and Morton	Surg. Gynec. & Obst. **25**: 621 (Dec.) 1917	3,490	65	1.86	33	0.94	50.7
Osnabrueck	Otte	München. med. Wchnschr. **54**: 2473, 1907	7 years total cases	...	‡	‡	‡	‡
	Pfannenstell	Zentralbl. f. Gynäk., 1908, No. 1	2,000†	...	§	§	§	§
Combined Statistics	von Lichtenberg	Centralbl. f. d. Grenzgeb. d. Med. u. Chir. **11**: 129, 1908	23,673	440	1.9			
Peter Bent Brigham Hospital	Cutler and Hunt	.....	1,562	55	3.52	11	0.7	20.0

* Amended to include pulmonary embolism.
† Not recorded for whole series.
‡ No lung complications.
§ No deaths from lung complications. No pneumonia.

The condensed comparison of statistics given in Table 2 demonstrates the seriousness of this complication and shows well the increase in morbidity due to more careful study in the later reports with the resultant fall in the mortality figures. The comparison with Osler and McCrae's [19] combined statistics is only further evidence of the fallacy of simple statistics, and undoubtedly the sources of their facts were relatively incomplete studies. The mortality figures compare better with Osler and McCrae's [19] estimate of a .53 per cent. mortality in pneumonia in the physically infirm. This is interesting in the light of recent studies on pneumococcus types. Whipple [3]

19. Osler, William, and McCrae, Thomas: Modern Medicine, Philadelphia, Lea and Febiger, 1913, **1**:202.

has shown that the predominant type in postoperative pneumonia is the Group IV pneumococcus, which agrees with Stillman's [20] findings that it is commonly present in healthy mouths; but Dochez and Cole [21] have demonstrated its relatively low virulence. The work of Wadsworth,[22] showing that infection in pneumonia depends on the virulence of the organism versus the resistance of the body, is merely an elaboration of now well known facts; and the findings by Whipple that the predominant organisms belong in Group IV is to us evidence

TABLE 2.—General Surgery — Postoperative Pneumonia

Clinic	Author	Reference	No. of Cases	Pneumonia Morbidity		Pneumonia Mortality		Mortality % of Morbidity
				No.	Per Cent.	No.	Per Cent.	
Mayo	Beckman	Collected Papers Mayo Clinic, 1910, p. 594	3,657	10	0.27	5	0.14	50.0
Mayo	Beckman	Collected Papers Mayo Clinic, 1912, p. 738	5,835	19	0.32	6	0.10	31.5
Mayo	Beckman	Collected Papers Mayo Clinic, 1913, p. 776	6,825	27	0.39	0	0.00	0.0
Roosevelt Hospital, N. Y.	Booth	Med. Rec. **89**: 582, 1916	2,612	23	0.9	7	0.26	30.4
New York Hospital	Burnham	Surg. Gynec. & Obst. **19**: 468, 1914	1,413	15	1.06	7	0.50	46.6
Massachusetts General Hospital	Cutler and Morton	Surg. Gynec. & Obst. **25**: 621 (Dec.) 1917	3,490	40	1.14	22	0.63	55.0
Montreal General Hospital	Armstrong	Brit. M. J. **1**: 1141, 1906	2,500	30	1.20	22	0.88	73.3
Leipzig	Laewen	Zentralbl. f. Chir. **4**: 96, 1907	9,755	180	1.8	113	1.15	63.0
Presbyterian Hospital	Whipple	Surg. Gynec. & Obst. **26**: 29 (Jan.) 1918	3,719	97	2.60	25	0.67	25.6
Peter Bent Brigham Hospital	Cutler and Hunt	.....	1,562	25	1.6	8	0.51	32.0
		Totals.....	41,368	466	1.12	215	0.41	46.1
	Osler and McCrae	Modern Medicine, **1**: 202, 1913	139,101	499	0.35			

that we must look further than some simple irritative phenomenon for the etiologic factor. This we firmly believe, and our investigation this time seems to demonstrate additional factors to our findings and conclusions drawn from a previous study in 1916.

Among the studies of postoperative pneumonia are many reports on the occurrence of pneumonia after laparotomy; and the increased incidence in this field is very striking.

20. Stillman, E. G.: J. Exper. Med. **24**:651 (Dec.) 1916.

21. Dochez and Cole, in Forchheimer's Therapeusis of Internal Diseases, New York, D. Appleton & Co., 1914, **5**:470.

22. Wadsworth: Am. J. M. Sc. **127**:851, 1904.

The average morbidity of pneumonia in laparotomies shown in Table 3 is further substantiated in other reports in which the actual number of laparotomies performed is not given. Thus, in Whipple's last paper,[3] of the ninety-seven postoperative pneumonias, eighty-eight occurred in patients on whom celiotomy had been performed. Certainly, the comparison with general surgery is striking. Thus the pneumonia morbidity for general surgery is 1.12 per cent. compared with 4.4 per cent. for laparotomies.

TABLE 3.—LAPAROTOMIES — PNEUMONIAS (POSTOPERATIVE)

Clinic	Author	Reference	Number of Cases	Morbidity	
				No.	Per Cent.
Zurich	Kroenlein	Verhandl. d. deutsch. Gesellsch. f. Chir. **34** : 131, 1905	1,409	8	0.56
Massachusetts Gen. Hosp.	Cutler and Morton	Surg. Gyec. & Obst. **25** : 621 (Dec.) 1917	1,181	20	1.7
Breslau	Kausch	Verhandl. d. deutsch. Gesellsch. f. Chir. **34** : 117, 1905	1,881	45	2.4
Hamburg	Kuemmel	Verhandl. d. deutsch. Gesellsch. f. Chir. **34** : 113, 1905	1,754	43	2.5
Berlin	Bibergeil	Arch. f. klin. Chir. **78** : 339, 1905.....	3,909	135	3.5
Heidelberg	Czerny	Verhandl. d. deutsch. Gesellsch. f. Chir. **34** : 109, 1905	1,302	52	3.9
Leipzig	Laewen	Beitr. z. klin. Chir. **50** : 2, 1906.....	1,829	98	5.4
Munich	Gebele	Beitr. z. klin. Chir. **43** : 2, 1904.....	1,196	77	6.43
Breslau	Henle	Verhandl. d. deutsch. Gesellsch. f. Chir. **30** : 240, 1901	1,787	143	8.0
Königsberg	Wolff	Deutsch. Ztschr. f. Chir. **88** : 71, 1907	971	121	12.5
Peter Bent Brigham Hosp	Cutler and Hunt	.....	856	21	2.4
		Average morbidity.....	.....	...	4.48

There has been much discussion of the etiologic factors. The most emphasized factor is the presence of sepsis and the easy pathways to the lung and pleural cavity both by the blood vessels and the lymphatics. In addition, hypostasis, due to confinement to bed, is increased by the unconscious splinting of the abdominal wall through partial inhibition of diaphragmatic movements. Further, the motion which does occur is likely to set free minute thrombi in the operative field, especially if there has been much trauma, and cause small pulmonary emboli. Still further, laparotomy exposes surfaces unused to the outer world, and evaporation and chilling take place easily. Bibergeil [12] and Kelling [18] especially emphasize the rôle of sepsis, and Armstrong [8] is impressed particularly with the effect of chilling.

Pulmonary complications most frequently occur after operations involving the epigastrium. In our former study [2] the percentage of total pulmonary complications in the upper abdominal cases rose to 7.7, and Laewen [23] reported 8.1 per cent. in this field. In this study, the epigastric operations showed a postoperative pulmonary morbidity of 8.0 per cent. The etiologic factors just mentioned are only further

23. Laewen: Footnote 11, second reference.

emphasized by all workers in this field. The brilliant anatomic work of Sabin [24] demonstrates the ease with which lymphatic channels may carry sepsis or emboli from the epigastrium; and the reports of Kelling,[18] Gee and Horder,[25] Bibergeil,[12] Laewen,[11] Homans [26] and others all emphasize the possibility of such emboli occurring. With a preexisting sepsis, the result is too evident. Possibly this is rather startling to those unaccustomed to summarize results; for, as we pointed out in a former paper, it is in this field that the best surgeons do the majority of the work. The less experienced surgeons may possibly undertake pelvic surgery or the removal of the appendix, but when it comes to the gallbladder and stomach they feel the need of a consultant. And yet the etiology is obvious: first, the possibility of sepsis; next the perfect systems of drainage to the lungs; then the hypostasis increased by protective muscle spasm and dressings, and, lastly, the constantly moving field to loosen up thrombi! We consider that such thrombi or agglutinated masses occur both in veins and lymphatics, and in speaking of embolism we mean the transmission of such masses to the lungs both by venous and lymphatic channels. In view of the subsequent corroboration, Ranzi's [9] insistence in 1908 on the embolic nature of pulmonary complications was most creditable.

The only other pulmonary complication which has received any great amount of attention is the group of pulmonary embolism of which the high fatality and terrifying clinical picture forces its recognition and importance. Ranzi [9] of Vienna, Kelly of Baltimore and Wilson [27] of the Mayo Clinic have discussed this group very thoroughly, and all agree on sepsis and vascular trauma as the important etiologic factors. The average of the three studies just mentioned shows that pulmonary embolism occurred once in every 744 operations, whereas in this report it occurred once in every 521 cases in which operation was performed.

In 1914, Burnham [28] presented a most interesting study on pleurisy and empyema from the Presbyterian Hospital, New York. In 13,013 operations, pleurisy, either dry or with effusion, occurred fifty-nine times (0.45 per cent.) with one fatality. Empyema occurred six times and was fatal in each instance. Burnham believes this is characteristic of postoperative empyemas. The etiology of these conditions is seen at once when we study the individual cases. Thus all of the

24. Sabin, F. R.: Science **44** (N. S.):145, 1916.

25. Gee and Horder, in Allbutt and Rolleston's System of Medicine, New York, the Macmillan Company, 1910, **5**:536.

26. Homans, J.: Johns Hopkins Hosp. Bull. **20**:125, 1909.

27. Wilson: Collected Papers Mayo Clinic, Philadelphia, W. B. Saunders Company, 1912, p. 727.

28. Burnham: Surg., Gynec. & Obst. **19**:468, 1914.

empyemas followed abdominal operations for either local or general peritonitis, and the great majority of the pleurisy cases also followed abdominal operations in the presence of infection.

This report of Burnham's points the advantage of analyzing together all pulmonary complications; for each group throws much light on the others. One of the outstanding factors in the etiology of these complications is sepsis. It is no exaggeration to say that some degree of infection was present in the field of operation in 75 per cent. of all cases in this study in which pleurisy, empyema, pulmonary embolism or pneumonia developed. The route by which sepsis is transferred to the pleural cavity or lung varies in different cases, but its very presence emphasizes the part the circulation, either vascular or lymphatic, must play in its transportation. The embolic theory is only further substantiated by such evidence.

We have recently seen a striking example. For several days, a vigorous man had been suffering from a scalp infection, and twenty-four hours before death an area from 4 to 5 inches in diameter, the seat of a staphylococcal cellulitis, had been excised down to the cranial bones. At necropsy, the lungs showed minute abscesses, some on the pleural surface. Several of these had ruptured, a fibrinopurulent pleuritis resulting. In this particular instance, the infection was terminal, of course, but it demonstrates the method of pulmonary infection.

The Rôle of the Anesthetic in Postoperative Pulmonary Complications.—For years, the term "ether pneumonia" has been used and still is used to apply to postoperative pulmonary disorders. This is unfortunate, since it unjustly lays blame on the anesthetic. Henle,[6] Gottstein [29] and Mikulicz [15] reported more pulmonary complications under local anesthesia than under general inhalation anesthesia, and the experimental work of Poppert,[30] Offergeld,[31] Hoelscher [32] and of Ladd and Osgood [33] demonstrates that ether when well given by the open drop method cannot be considered as a real factor in resulting pulmonary lesions. These investigators only confirm the clinical experience of such authorities as Bevan,[34] Keen,[35] Herb [36] and Gatch [37]

29. Gottstein: Arch. f. klin. Chir. **57**:409, 1898.
30. Poppert: Deutsch. Ztschr. f. Chir. **67**:505, 1902.
31. Offergeld: Arch. f. klin. Chir. **83**:505, 1907.
32. Hoelscher: Arch. f. klin. Chir. **57**:175, 1898.
33. Ladd, W. E., and Osgood, G.: Ann. Surg. **46**:460 (Sept.) 1907.
34. Bevan, A. D.: Tr. Am. Surg. A. **33**:21, 1915; ibid. **29**:177, 1911.
35. Keen: Boston M. & S. J. **173**:831, 1915.
36. Herb. I. C.: Ether: Simplicity in Its Administration, J. A. M. A. **66**: 1376 (April 29) 1916.
37. Gatch: Tr. Am. Surg. A. **29**:196, 1911.

that the irritant action of ether vapor varies with its concentration and that when the anesthetic is given in closed masks and carelessly the aspiration of mucus may be a factor in postoperative lung complications, but that in good and expert hands it is safe and rarely at fault. And yet, how seldom it is in expert hands! Surely, the majority of all anesthesias are given by the house officers or nurses in hospitals, or in private practice, except in the larger centers, by the family physician whose training has not been extensive. Such being the case, if poorly administered anesthesia was the cause of pulmonary complication, why do we not see it more frequently? Consider how often all experienced surgeons have seen badly anesthetized patients make an uneventful recovery. And further, let us recall the days when ether inhalations were given for consumption! There is, indeed, scant evidence to support the view that these postoperative pulmonary complications are due to the anesthetic except in those cases with a definite preoperative pathologic condition of the lung.

Our first paper in 1915 and Whipple's second paper in 1918 reported a higher percentage of pulmonary complications in the winter months. We will show later in this analysis the same tendency. It is well known that simple pneumonia occurs more frequently in the winter months (Osler [38]), and yet no satisfactory explanation of this has been given, for in some consistently cold climates the percentage is low, and again in Southern districts it is very high.

There has been much conflicting experimental evidence to show the effect of chilling with reduction of body temperature in the etiology of respiratory infections (Marchand,[39] Miller and Noble,[40] Hill [41]). The recent work of Mudd and Grant [42] would seem to show that chilling plays an important rôle in allowing bacteria which are always present to get a start. And the clinical experience of such authorities as Bibergeil,[12] Kelling [18] and Armstrong [8] led them to state that chilling of the internal body cavity by cool packs during operation was one of the important factors in the causation of these postoperative lung complications.

The recent interest shown in the effect of atmospheric humidity in steam heated buildings has led us to doubt much of the experimental and clinical evidence presented as to the part chilling alone plays.

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38. Osler, William: Principles and Practice of Medicine, New York, D. Appleton & Co., 1910.

39. Krehl and Marchand: Handb. der Allgem. Pathologie, Leipzig, Hirzel, 1908, **1**:108.

40. Miller, J. A., and Noble, W. C.: J. Exper. Med. **24**:223 (Sept.) 1916.

41. Hill: Brit. Med. Research Committee, 1919, S. R. Series 32.

42. Mudd, S., and Grant, S. B.: J. M. Research **40**:53 (May) 1919.

The papers of Ellsworth Huntington [43] are enlightening along these lines. His studies would seem to show that it is the dryness and not the coldness of the air which is the important factor. External air has a wide variation, but approximately 70 per cent. can be taken as a satisfactory average of humidity, whereas in heated buildings it drops to 25 or 30 per cent. Moreover, with the humidity at 70 per cent., we can be quite comfortable in temperatures near 60 F., although in our houses in winter we demand at least 70 F. The mortality statistics Huntington presents are very suggestive and throw light on the relation to chilling. For example, Mudd and Stewart cooled themselves before an electric fan while stripped, and breathing deeply with their mouths open. This probably produced an excessive dryness in their throats and prevented the action of immune substances. Possibly in this small field itself, we can obviate serious consequences by early inhalation of vapors and a correction of the humidity in our operative recovery rooms.

We agree with Whipple [3] that the type of pathologic pulmonary condition in many cases resembles that described by Woillez,[44] being an acute diffuse lesion; but as we will show later we do not think the anesthetic alone is responsible for this. Group IV organisms are common in the mouths of healthy people (Stillman [20]), but postoperative pneumonia even when the anesthetic is poorly administered is uncommon. There must be something beyond the simple irritation of the anesthetic and the humidity or chilling to bring about so much definite pulmonary disease. And again, how would this affect operations under local anesthesia? A great number of observers and investigators, including Henderson,[45] Boothby,[46] Magaw,[47] Kelling [18] and Mortimer,[48] believe the anesthesia plays a minor rôle, and we find ourselves in agreement with them.

PRESENTATION OF MATERIAL

This study covers all surgical cases admitted to this hospital in the year 1919. During this period there were 2,032 total surgical admissions, but actual operations under an anesthetic were performed on only 1,562 patients. The other 470 patients either were not operated

43. Huntington, E.: Mod. Med. **1**:13 (May) 1919; ibid. **14**:10 (May) 1920.

44. Woillez: Traité cliniques der maladies aiguës des organes respiratoire, Paris, 1872.

45. Henderson: Collected Papers Mayo Clinic, Philadelphia, W. B. Saunders Company, 1913, p. 701.

46. Boothby, W. M.: Team Work, J. A. M. A. **67**:539 (Aug. 12) 1916; J. Pharmacol. & Exper. Therap. **5**:379, 1914.

47. Magaw: Surg., Gynec. & Obst. **3**:795, 1906.

48. Mortimer: Med. Press., 1919, N. S., CVIII, 505.

on or were submitted to some simple procedure without an anesthetic, as cystoscopy or the application of a plaster cast. Among these cases, no pulmonary complications arose during the patients' stay in the hospital, which is evidence that the pulmonary complications occurring among surgical patients is in some way directly referable to the operative procedure.

Of these 1,562 patients, fifty-five, or 3.52 per cent., developed a definite postoperative lung disorder. We have summarized these cases in Table 4, and classified them as pneumonia, bronchitis, pleurisy, lung abscess, empyema or pulmonary embolism. In addition, we have taken the cases of pulmonary tuberculosis that showed a serious exacerbation of the disease after operation, whether recognized before operation or afterward. The cases in which a pulmonary lesion (pneumonia) brought about operation through mistaken diagnosis and also the cases in which operation was performed for lung abscess and empyema are discussed, but are not included among the fifty-five postoperative lung complications. Among these fifty-five cases, there were eleven deaths, 0.7 per cent. mortality for all operated cases and a mortality percentage of morbidity of 20. This means that approximately one in every twenty-eight patients operated on will have a pulmonary complication, and that one in every 142 will die of such a complication. Such figures, which appear to be true for all clinics, are most disconcerting, but they are nevertheless incontrovertible.

It is true that statistics often lead to false assumptions, and in our problem a thorough understanding of the reasons underlying the operation in each case must be grasped. Thus, emergency cases may demand immediate operation despite the risk of a serious pulmonary complication. Again, it must be remembered that in a great number of fatalities due to various factors, pneumonia will be found at necropsy. Cases in which the lung condition is terminal and not the chief cause of death have occurred several times in this group studied, but these cases are not included as postoperative complications. A patient with diffuse general peritonitis who dies evidently from the peritoneal intoxication and infection may have a terminal pneumonia which, however, is not to be considered as a postoperative complication.

To be sure of our figures every one of the 2,032 histories was carefully gone over; the clinical charts and postoperative notes were studied in order that all cases should be included. We believe that our high postoperative pulmonary morbidity (3.52 per cent.) is due to the fact that our figures are really very accurate because of the careful records and abundant postoperative notes; for in a teaching hospital, the histories are elaborate and the postoperative care a constant source of discussion. Without this added attention many of the simpler complications, such as pleurisy and bronchitis, may be entirely neglected in the postoperative notes, even if observed.

Having found a number of lung complications, there is a further difficulty in classifying them. The line between pneumonia and bronchitis is not always clear. This is another reason for studying the groups together as an entire anatomic division and not merely the pneumonias alone or embolism alone.

Pneumonia.—As previously stated, and in agreement with other investigators in this field,[49] the great proportion of serious postoperative pulmonary complications fall into the pneumonia group. Thus, we have twenty-five pneumonias in fifty-five total pulmonary complications of 1,562 operations, or almost 50 per cent. of all the complications; and eight, or 72.7 per cent., of the eleven fatalities. It is probable, also, that we have classified among our bronchitis cases some mild pneumonias. Especially may this be true when we realize the atypical picture and clinical course often presented by the postoperative type of pneumonia and the obscuring of any of these symptoms by other postoperative difficulties. The latter are legion. The rise in respiratory rate in practically all upper abdominal incisions owing to an attempt on the part of the patient to retard movement by shallow respiration, when further complicated by a rise in temperature due to wound sepsis or primary sepsis, and finally some resultant hypostatic congestion at the lung bases, are but a few of them. We have taken as the criteria necessary to include a case as postoperative pneumonia, definite physical signs, such as dulness, bronchial breathing and râles, with the accompanying rise in pulse, temperature and respirations, often cyanosis and sometimes pain and chill with onset.

Lobar Pneumonia.—A small percentage, only four cases (7.2 per cent.) of our pulmonary complications were of the lobar pneumonia type. This is in conformity with our opinion as to the general etiology of such complications which result as a rule in the bronchopneumonia type. In fact, the morbidity percentage of lobar pneumonia in relation to the total number of operations is 0.25 per cent. as opposed to a morbidity percentage for bronchopneumonia of 1.34, or five times as frequent. All patients recovered. The ages ranged from 22 to 40, and, with one exception, the patients were considered good risks. In three cases ether was used, in one gas-oxygen; there were no protracted operations. All four patients developed acute symptoms within twenty-four hours, with elevation of pulse, temperature and respirations and the physical signs of beginning consolidation. Recovery in all cases occurred after an average of seven days. One patient, after a normal period of twenty-four hours, suddenly had a reinfection, and all the

49. Lord, F. T., in discussion on Robinson, Samuel: Thoracic Diseases, J. A. M. A. **67**:556 (Aug. 19) 1916; Footnotes 3, 9 and 16, second reference.

TABLE 4.—Postoperative Lobar Pneumonia

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9756 N. P. ♂, 22 January	Inguinal hernia, bilateral	Well developed and fairly well nourished; 137 pounds; heart normal; right chest normal; left chest, base posteriorly, an area of rather harsh breathing; white blood cells 10,000; blood pressure 125/75	Repair ..... Supine position	Ether (drop) 9 ounces, well taken; became light and coughed in middle of operation: anesthesia, 1 hour 20 minutes; operation 1 hour 15 minutes	In 24 hours, consolidation, right base, dulness, râles, increase in whispered voice; 48 hours, bloody sputum, cough; fall of temperature by lysis, normal 5th day; discharged well, 17th day
2	10173 M. M. N. ♀, 40 March	Cholecystitis, acute; empyema of gallbladder; cholelithiasis	Well developed and nourished; sick appearing, in distress; rapid respiration; frequent colds and bronchitis; chronic yellow sputum; left chest normal; right chest, dulness; whispered and spoken voice moderately increased; heart normal; weight 135 pounds; blood pressure 130/90	(1) Cholecystectomy; appendicectomy, incidental; accidental choledochostomy, drainage (2) Repair of common bile duct, drainage Supine position	(1) Ether (drop) 7½ ounces, well taken; anesthesia, 1 hour 30 minutes; operation, 1 hour 35 minutes (2) Gas-ether (drop) 7 ounces, well taken; anesthesia, 2 hours 10 minutes; operation, 2 hours 5 minutes	(1) Stormy recovery; pain in chest and cough, abrupt rise of temperature, pulse and respirations; 48 hours, dulness, bronchial breathing, right base, rusty sputum, increasing symptoms; temperature dropped by lysis, 11th day normal, 24 hours later 103 F.; signs and symptoms of reinfection, same area but not so marked, returned to normal by lysis 22d to 29th day (2) Immediate postoperative rise in temperature, pulse and respiration for 4 days; no absolute sign of pulmonary involvement; discharged well 24 days later
3	10219 H. K. ♀, 30 March	Salpingitis, bilateral, acute	Powerfully developed, obese; 200 pounds; heart and lungs negative; teeth fairly good; blood pressure 120/80; history of morning cough for several years, considerable yellow sputum, frequent colds, occasional night sweats and chills; moderate dyspnea on exertion	Bilateral salpingectomy; drainage for acute pelvic peritonitis; ventral suspension; appendicectomy, incidental Trendelenburg position	Ether (drop) 6 ounces; anesthesia, 1 hour 5 minutes; operation, 1 hour 3 minutes; hysterical, vomited toward close of induction	Fair recovery; dyspneic, pain in back, consolidation of right chest in front, high pitched breath sounds and crackling râles; left chest, respiratory note accentuated, moist râles, 24 hour postoperative cough; highest temperature 102.4 F., dropped by lysis to normal the 8th day; discharged well 20th day
4	10547 A. S. ♂, 28 May	Nephroptosis, left	Well developed and nourished; 124 pounds (average 140); heart and lungs negative; blood pressure, 110/60	Exploration of left kidney; partial decapsulation and nephropexy Right lumbar position	Gas-oxygen; anesthesia, 1 hour 40 minutes; operation, 1 hour 20 minutes; quiet throughout; pulse and respirations unchanged	Good recovery; rapid rise in temperature, pulse and respiration in 24 hours, temperature 103.6 F., pulse 143, respirations 40; signs of consolidation, right base; sputum negative for tuberculosis; white blood cells on 10th day 12,000; recovery by lysis 11th day; discharged well 19th day after operation

* In this and the following tables, ♂ represents male, and ♀ female

signs of pneumonia returned. The explanation of reinfection in simple pneumonia is not clear, and in the type under discussion is even more difficult.

Because of the greater frequency of the bronchopneumonic type, an especially careful study of the signs and symptoms in these four cases was made, but they appeared to be decidedly of true lobar type. The explanation for the complication in Case 2 is not difficult, and the preoperative examination undoubtedly made the surgeon anxious on this very score. The patient was 40 years old, gave a history of chronic cough with sputum, susceptibility to bronchitis and moreover there were definite signs of an already existing pulmonary disorder. In addition, the operative field was the epigastrium and sepsis was present. The ease with which organisms could reach the lungs either by embolism or by direct lymphatic extension is too evident. A pulmonary complication was to be expected. In the other cases, there is no such definite preexisting pathologic condition of the lungs, although Case 3 gave a history of night sweats, chills and morning productive cough. Also, the pelvis in this case presented a focus of acute inflammation from which bacteria could be spread and a difficult anesthesia undoubtedly played a part. In Case 1, the patient was an excellent risk, the operation was performed rapidly and without accident or anesthetic difficulty. It is such cases that need the closest scrutiny if we are to find any explanation for the resultant pneumonia. The clinical picture of pneumonia was classical, and our difficulty lies in determining its etiology. The spitting up of bright blood may be interpreted as the evidence of an early embolus from the operative field, probably while still under anesthesia, as there was no history of pain. The prompt recovery aids this explanation in that the lesion was due more to a change of circulatory pressures and congestion than to a true infective process. It is just this type of complication that demands explanation above all others. The anesthesia was well given and well taken, and there were no technical difficulties. The complicating lesion was discrete and localized, and we felt at the time that an aseptic embolus had been set free from the operative field, probably during operation, and had lodged in the lung. Since it was sterile, recovery from it was rapid. In Case 4 the explanation rests: (1) on the juxtaposition of the operative field to the pleura, and (2) on the mobility of the part. It seems probable that in the manipulation of a kidney operation there is some trauma through the diaphragm to the lung; if, in addition to this, minute emboli are showered in and hypostasis occurs, enough consolidation results to give the signs of pneumonia.

TABLE 5.—BRONCHOPNEUMONIA

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9767 M. F. ♀, 18 January 6:15 p.m.	Appendicitis, acute, perforated with peritonitis	Well developed and nourished; heart and lungs negative, three-day symptoms; on admission, temperature 101.4 F., pulse 170, respirations 26, white blood cells 23,000	Appendicectomy, drainage Supine position (forenoon after admission)	Ether (drop) 7½ ounces; anesthesia, 45 minutes; operation, 50 minutes; quiet, color good, pulse very rapid, 200	Good recovery; Fowler's position; at 4 p. m., temperature 104 F., pulse 165, respiration 45; examination of chest 48 hours after operation, questionable bronchial breathing, left base; temperature, pulse and respiration still high, no pain in chest or cough, moderate drainage; temperature, pulse and respiration continued elevated but general condition improving; 19th day after operation, suddenly became cyanotic and dyspneic; examination of chest, bronchial breathing, both backs, more marked on left, scattered moist râles; died 2 days later, 22d day after operation. Necropsy: bronchopneumonia, sepsis from peritonitis; general peritonitis, confluent bronchopneumonia
2	9798 J. W. ♀, 28 January	Cholecystitis, chronic cholelithiasis	Well developed, obese; heart, soft, systolic murmur at base; lungs negative; blood pressure 118/80; history of some dyspnea and palpitation	Cholecystectomy, choledochostomy Supine position	Ether (drop) 16 ounces; anesthesia, 2 hours 15 minutes; operation, 2 hours 10 minutes; pulse and respirations high, difficult to relax; marked nausea and vomiting when conscious	Stormy recovery; patient very intolerant of pain; second day after operation, temperature 102 F., pulse 140, respirations 40; chest not examined; no cough; temperature, pulse and respirations remained high five days and dropped by lysis to normal 20th day; no wound sepsis; discharged well, 54th day
3	10020 J. Mc. ♂, 23 February	Inguinal hernia, left	Well developed and nourished; heart and lungs negative; pharynx injected; temperature 99 F.; subject to "chronic cold"; abscess at root of tooth which discharges at intervals	Repair ..... Supine position	Ether (drop) 3½ ounces; anesthesia, 30 minutes; operation, 25 minutes; well taken, conscious when returned to bed	Good recovery; 24 hours later, temperature 102 F., some pain in chest and cough, respirations 28-45; temperature 99 to 102 F., pulse 86-110, respirations 24-32, dropped by crisis 8th day; no definite signs found in chest but roentgen-ray examination one week after operation revealed diffuse mottled density throughout both chests; discharged well, 17th day
4	9996 S. W. ♀, 39 February	(1) Chronic cystic mastitis (2) Tubo-ovarian abscess	(1) Well developed negress; 123 pounds; chronic cough and sputum; history of precordial pain, palpitation; lungs negative; tonsils and pharynx injected; systolic murmur; blood pressure 220/120 (2) See postoperative course	(1) Removal of left breast and axillary glands Supine position (2) Bilateral salpingo-oophorectomy, incidental appendicectomy, drainage Trendelenburg position	(1) Ether (Connell); quiet throughout; anesthesia, 1 hour 40 minutes; operation, 1 hour 35 minutes (2) Ether (drop) 7 ounces; anesthesia, 1 hour 10 minutes; operation, 1 hour; quiet throughout	(1) Good recovery; 6th day sudden rise in temperature, pulse and respirations; 7th day, temperature 104.4 F., pulse 140, respirations 48; septic chart and elevation of temperature, pulse and respirations until 27th day when abscess in pelvis was located and drained by operation (2) Poor recovery; continued elevation of temperature, pulse and respirations; pain in right chest and cough; examination of chest 3 days after second operation revealed dulness and râles at right base; coughing and pain; on 11th day a patch of bronchial breathing, dulness and increased spoken voice appeared in left base, rusty sputum, severe cough; fall of temperature, pulse and respirations by crisis 15th day; discharged well, but weak, to convalescent home 57 days after admission

5	10189 V. M. G. ♀, 24 March	Retroversion of uterus	Rather frail appearing, 106 pounds; no cardiac murmurs but history of dyspnea and precordial pain on exertion in the past; lungs normal; blood pressure 92/40	Dilatation and curettage; ventral suspension of uterus; appendicectomy, incidental Lithotomy and Trendelenburg positions	Ether (drop) 7 ounces; anesthesia, 1 hour 10 minutes; operation, 1 hour 10 minutes; well taken	Stormy recovery; rapid, irregular pulse, 150-180; respirations, 20-25; temperature not above 100 F.; 3d day, coarse crackling râles in left side and few in right; gradual rise in temperature to 102; dulness and râles at left base, much coughing; 14th day, sepsis in wound; persistent dulness in left base with diminished breath sounds but no râles; same sounds in right axilla; gradual fall by lysis to normal in 17 to 20 days; discharged well, 28th day
6	10343 M. E. C. ♀, 50 April	Ovarian cyst	Fairly well developed and nourished; 140 pounds (200 pounds 8 years previously); soft systolic murmur; lungs normal; blood pressure 130/80	Removal of ovarian cyst, bilateral salpingectomy, ventral suspension of uterus; incidental appendicectomy Trendelenburg position	Ether (drop) 7 ounces; anesthesia, 1 hour 25 minutes; operation, 1 hour 25 minutes; quiet	Fair recovery; 1st day after operation, dulness and bronchial breathing right base, temperature 101 F., pulse 100, respirations 38; two days later pleurisy pains persisting for several days; consolidation spread throughout entire right back with râles but no dulness, left side; sputum negative for tuberculosis, full of diplococci; discharged against advice 15 days after operation, dulness and râles present throughout right back with slight dulness and a few râles at left base
7	10654 L. F. W. ♂, 76 June	Epigastric hernia strangulated	Dyspnea 10 years, hacking cough 14 years, rarely sputum; blood pressure 190/70; heart, systolic murmur, slight enlargement; lungs, scattered fine râles posteriorly both sides; weight 100 pounds	Repair ..... Supine position	Gas-oxygen, small amount of ether; anesthesia, 1 hour 20 minutes; operation, 1 hour 10 minutes; well taken; irregular but not rapid pulse	Good recovery, but within 24 hours rise in pulse, temperature and respiration; temperature 101 F., pulse 110, respirations 40; breathing labored; pulse poor; enormously loud tracheal râles obscured pneumonic signs, which were present on both sides; died 9th day after operation; no necropsy
8	10723 T. J. R. ♂, 13 June	Ventral hernia, postoperative; inguinal hernia, right	Rather delicate boy; chorea 4 years; subject to tonsillitis and colds; 85 pounds; heart and lungs clear; active coryza	Repair ..... Supine position	Ether (drop) 5 ounces; anesthesia, 1 hour 5 minutes; operation, 1 hour; quiet anesthesia	Good recovery, but steady rise in temperature, pulse and respirations; 3d day after operation, temperature 103 F., pulse 120, respirations 35; râles at both bases with dulness beneath right scapula and diminished breath sounds, considerable cough; returned to normal by lysis 12th day; discharged well, 20th day
9	10752 C. V. ♂, 27 July	Acute appendicitis with abscess	Well nourished but sick appearing; intermittent precordial pain 9 months; heart and lungs normal; temperature 100.7 F.; pulse 100; white blood cells 20,600; urine showed s.p.t. albumin, few granular casts, few white blood cells	Appendicectomy, drainage three days after onset Supine position	Ether (drop) 9 ounces; anesthesia, 1 hour; operation, 55 minutes; quiet anesthesia; respirations rapid	Fowler's position; stormy recovery; in 48 hours temperature 102.2 F., pulse 170, respirations 60; definite consolidation, both bases and right superior lobe; tracheal râles; labored breathing; progressively worse; consolidation of entire right chest 5th day; died 6th day after operation; necropsy, confluent bronchopneumonia, both lower lobes and portions of middle lobe
10	10849 F. S. ♂, 15 July	Undescended testicle; inguinal hernia, left	Well developed and nourished; 156 pounds; heart negative; lungs, "occasional squeaks"; operation deferred five days on account of coryza and bronchitis; blood pressure 120/65	Left orchidectomy; repair Supine position	Gas-oxygen, trifling amount of ether; anesthesia, 1 hour 5 minutes; operation, 55 minutes; smooth anesthesia	Temperature 101.4 F., pulse 120, respirations 40 at 4 p. m.; following day, examination of lungs revealed rather harsh breathing with coarse râles, both apices; dulness in left base at back, bronchial breathing and bronchophony; cough, sputum, diplococci, not of type 1 or 2; temperature, pulse and respirations dropped by lysis to normal 9th day after operation; discharged well, 15th day

TABLE 5.—BRONCHOPNEUMONIA—*Continued*

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
11	11140 D. McL. ♂, 46 September	Hypertrophy of prostate	Well developed and nourished; weight 180 pounds; heart and lungs negative; blood pressure 128/82	Suprapubic cystotomy with excision of median bar Trendelenburg position	Gas-oxygen small amount of ether; anesthesia, 1 hour 50 minutes; operation, 1 hour 35 minutes; well taken	Good recovery; in 24 hours, temperature 102.4 F., pulse 120, respirations 36; slight cough; white blood cells 20,000; bronchovesicular breathing and increased whispered voice sounds at right base, dulness, moist râles at both bases; temperature, pulse and respirations dropped by lysis to normal 5th day after operation; lungs clearing; discharged well, 18th day
12	11500 M. M. ♂, 60 December	Abscess of prostate; abscess of epididymis, bilateral; cystitis	Well developed and nourished; heart and lungs negative, blood pressure 160/80; weight 124 pounds (at one time 180); looks sick and septic temperature; blood pressure down to 110/60 at operation	Bilateral epididymotomy; evacuation of scrotal abscess, drainage, 25 days after admission Lithotomy position	Gas-oxygen; anesthesia, 50 minutes; operation, 30 minutes; quiet anesthesia	Fair recovery; slight cough, diminished breath sounds, 2d day after operation; temperature, pulse and respirations similar to before operation until 5th day; temperature 102.6 F., 12 hours later 104.4 F., pulse 130, respirations 35; dulness over right upper lobe, diminished breath sounds; coarse crackling râles in both chests; died 8th day after operation; no necropsy
13	11505 F. J. C. ♂, 31 November	Bilateral inguinal hernia	Well developed and nourished; heart negative; lungs, relative dulness and distant voice sounds in lower right back and axilla; blood pressure 122/84; weight 157 pounds	Repair ..... Supine position	Ether (drop) 8 ounces; anesthesia, 1 hour 5 minutes; operation, 1 hour; coughed a little during induction, otherwise smooth	Good recovery, no vomiting; elevation of temperature to 103 F. on 2d day after operation, pulse 100, respirations 30; following day slight cough, patch of bronchial breathing, increased voice sounds, few median râles at tip of left scapula; temperature dropped by lysis to normal 6th day after operation; discharged well, 18th day
14	11424 F. McC. ♂, 52 October	Adenocarcinoma of stomach	Well developed and nourished; 135 pounds; blood pressure 134/70; blowing systolic murmur; lungs negative; history of palpitation and dyspnea; teeth poor; severe pneumonia thirty years before	Resection (sleeve) ..... Supine position	Procain, gas-oxygen, ether, 1 ounce; general anesthesia, 2 hours 40 minutes; operation, 3 hours; well taken	Fair recovery, no vomiting; following day, diminished breath sounds in right axilla; 2d day, evening, temperature 100 F., pulse 112, respirations 32; cough, râles over same area; pain in right side with deep breath; 6th day after operation, dulness, diminished breath and few crepitant râles in left axilla, pain on coughing; temperature dropped by lysis to normal 9th day after operation; discharged improved, 33d day
15	11386 F. P. W. ♂, 54 October	Trigeminal neuralgia (major, left)	Well developed and nourished; 175 pounds; blood pressure 112/78; heart and lungs negative; history of pneumonia fifteen years before and last year following operation for hernia and appendix	Avulsion of left sensory root Supine position	Ether (Connell); anesthesia 1 hour 50 minutes; operation, 1 hour 35 minutes	Good recovery; 2d day after operation, temperature 102.6 F., pulse 120, respirations 20; cough, coarse râles over bronchi, following day, temperature 103.8 F., pulse 112, respirations 20; continued high temperature, pulse and respiration not much accelerated, many moist râles; temperature dropped by lysis to normal 8th day; discharged well, 14th day
16	11156 G. H. S. ♂, 70 September	Stricture of urethra; periurethral abscess; urethral fistula (perineal)	Undernourished, emaciated colored man; 104 pounds; history of pleurisy, bilateral, malaria, chronic sputum and cough, night sweats, shortness of breath, precordial pain; teeth	(1) Perineal section, drainage of periurethral abscess Lithotomy position (2) Suprapubic cystostomy, retrograde cath-	(1) Procain 1% (local); operation, 1 hour 35 minutes (2) Procain 5%; 2 c.c. intraspinal; operation, 55 minutes	(1) Following morning, temperature 101.8 F., pulse 100, respirations 28; in the afternoon, normal; fair reaction (2) Poor recovery, irrational; 4 p. m., temperature 102.6 F., pulse 140, respirations 28; following day improved, temperature normal, pulse 120; 3d

			very poor; lungs, slight general dulness, bronchial breathing left axilla, coarse râles both lungs; systolic murmur; blood pressure 130/85; cough and bloody sputum present	eterization of urethra; drainage Supine-lithotomy positions		day after operation, temperature 100.6 F., pulse 110, respirations 40; general condition very poor; died 12th day after operation. Necropsy: chest, chronic bronchitis with bronchiectatic cavities and abscesses; acute purulent bronchitis; bronchopneumonia; chronic emphysema with emphysematous bullae; emphysema of mediastinum; chronic fibrous pleuritis
17	11215 I. P. ♂, 74 September	Hypertrophy of prostate; cystitis; pyonephrosis	Large, heavy, rather feeble man; weight 177 pounds; lungs negative; heart sounds feeble with marked irregularity; history of pleurisy, precordial pain, rare palpitation; severe influenza 1918; frequent dizziness; blood pressure 140/80	(1) Suprapubic cystostomy, drainage Trendelenburg position (2) Suprapubic prostatectomy, drainage Trendelenburg position	(1) Procain 1% (local); operation, 50 minutes (2) Gas-oxygen; anesthesia 45 minutes; operation, 30 minutes; quiet throughout	(1) Poor recovery, vomiting; general condition gradually improved; cough occasionally; slight pulmonary emphysema (2) Good recovery, no vomiting; following day, afternoon, temperature 101.6 F., pulse 110, respirations 28, numerous coarse moist râles and sibilant râles rather diffuse, right and left bases mostly; 3d and 4th days, temperature 103 F., pulse 120, respirations 30-36; many large coarse râles, no consolidation; loose cough; temperature, pulse and respirations on downward course; temperature normal 7th day; bronchial râles, profuse, brownish sputum noted on 10th day; died 13th day. Necropsy: chest, acute bronchitis; bronchopneumonia, chronic fibrous pleuritis
18	11694 H. B. ♂, 76 December	Hernia, inguinal, strangulated; 78 hours	Fairly well developed, undernourished, rather feeble; blood pressure 110/56; white blood cells 26,000; in bed three days with "a cold" before admission; heart negative; lungs, relative dulness, few moist râles at left base; breath sounds whistling, loud	Repair, reduction ..... Supine position	Gas-oxygen, very little ether; anesthesia, 1 hour 35 minutes; operation, 1 hour 15 minutes; well taken; pulse 148, respirations 36	Poor recovery, restless and irrational, getting out of bed; following day, temperature 101.4 F., pulse 110, respirations 30; râles at left apex and later throughout lungs; died 3d day after operation; no necropsy
19	11743 A. B. ♂, 65 December	Bilateral inguinal hernia	Well developed and nourished; weight 155 pounds; heart and lungs negative; blood pressure 120/60; teeth very poor; slight unproductive cough	Repair ..... Supine position	Gas-oxygen, few drops of ether twice; anesthesia, 1 hour 45 minutes; operation, 1 hour 25 minutes; well taken	Good recovery, no vomiting; 2d day after operation, temperature 102 F., pulse 180, respirations 24; patches of dulness and diffuse bronchitis; 4th day after operation, temperature normal, lungs clearing; discharged well, 18th day
20	11654 L. E. ♀, 69 December	Varix, internal saphenous system; ulcer, varicose	Fairly well developed and nourished; 150 pounds; heart negative; blood pressure 117/80; lungs, bronchovesicular breath sounds	Excision ..... Supine position	Gas-oxygen; anesthesia, 1 hour 45 minutes; operation, 1 hour 5 minutes; very quiet	Good recovery; temperature 98 to 100 F., pulse and respirations normal; 9th day after operation, temperature 102.5 F., pulse 100, respirations 28; dulness at right back, "crackles"; two days later temperature normal; discharged well, 23d day after operation
21	10634 B. T. D. ♀, 58 June	Carcinoma of rectum	Well developed and nourished; Weight 175 pounds; heart and lungs normal; blood pressure 180/100	First stage extirpation, sigmoid divided above tumor, ends sutured; colostomy just proximal to upper end Very marked Trendelenburg position	Ether (drop) 12 ounces; quiet, general condition good throughout, pulse steady at 70; anesthesia, 3 hours; operation, 3 hours 5 minutes	Good immediate recovery, but within 24 hours rise of temperature to 102 F., pulse to 125, respirations to 35; patient lethargic, increasing cyanosis, restless, abdomen negative; no cough; in 48 hours rapid rise in temperature, pulse and respirations; pulse irregular at 150, respirations 45, temperature 106 F.; died. Necropsy: bronchopneumonia, bilateral; carcinoma of rectum; postoperative wounds

Bronchopneumonia.—Into this class fall the majority of all postoperative pulmonary complications. In our series, twenty-one cases, or 38.1 per cent., of the total complications were of this type, as opposed to 7.2 per cent. of the lobar pneumonia group and 30.9 per cent. of the next largest or bronchitis group. Not only is this the largest group but its mortality figure also exceeds the combined mortality of all the other complications. Thus, of our eleven deaths in the fifty-five cases with pulmonary complications, eight patients succumbed to bronchopneumonia. There is, however, much danger in a too close study of the figures alone, for the majority of old people at necropsy show some terminal or accompanying bronchopneumonic process; and we have tried not to include cases of patients who have died of a terminal bronchopneumonia in which we felt this was not the really important factor. As we have already stated, this is the typical postoperative pulmonary complication, and a close scrutiny of this class demonstrates most clearly the factors which are of importance in their etiology. The picture here presented is often definite and striking, and the etiologic factors become evident; whereas in the minor complications, such as pleurisy and bronchitis, although the cause may be, and probably is, the same, the indefiniteness and lack of intensity of the clinical picture make it difficult to determine the true underlying causes.

In the first place, we are impressed by the fact that the patients as a whole are poor risks. Of the twenty-one patients, eleven were over 50 years of age, and the ages in the fatal cases were 13, 27, 58, 60, 70, 74, 76 and 76. In addition, there was an existing preoperative pathologic pulmonary condition or definite history of lung disability in ten instances (Cases 3, 4, 7, 8, 10, 13, 15, 16, 17 and 18). We would emphasize this, not that it is the chief etiologic factor in pulmonary complications, but because it is a factor that is frequently overlooked and to which little importance has in the past been attached. This is partly due to incomplete physical examinations, or to the system of operating in use in the majority of American clinics, whereby busy practitioners as attending surgeons to public hospitals do the bulk of the surgical work. It is really more the fault of the system than of the individual surgeon's lack of realization of the importance of such findings. There will always be emergency cases in which the local condition necessitates intervention irrespective of the lung findings; but what we would point out is that if this factor is understood, possibly local or gas-oxygen anesthesia, or a modification of the operative procedure may be sufficient to lessen the danger of a serious pulmonary complication. We believe that in this clinic this risk is quite well studied; we do adapt the anesthesia to the contingency, we do modify operation or if possible try to clear up the

lung condition before operation, and yet in this very class our morbidity and mortality figures are high. However, from experience we are convinced that without such precautions they would have been higher; and when one considers that of the eight patients that died, four were 70 years of age or more, the difficulties confronting our surgeons can be appreciated. Furthermore, a good many of the cases in the series included in Table 5 were so-called "septic" cases; four patients (Cases 11, 12, 16 and 17) were aged, with genito-urinary complications, cystitis, etc., from hypertrophied prostates or strictured urethra; two patients (Cases 1 and 9) had perforated appendixes, and in Cases 2, 4, 7 and 18 there was infection. The importance of existing sepsis in the etiology of postoperative pulmonary complication lies in the liability of minute emboli from such foci to reach the lungs either by blood stream or lymphatic extension. Eighteen cases were laparotomies, three of these patients having epigastric incisions. The incidence of pulmonary complications with laparotomies and especially with epigastric incision is admitted in the literature as very high; and the explanation of easy extension of infection by blood vessels and lymphatics, the usual hypostasis in the lung bases from incising the abdominal wall, etc., are a sufficient explanation.

This brings us to the point which we constantly wish to emphasize, that the anesthetic cannot be blamed per se for postoperative lung complications. A study of the anesthetics in this group of cases shows eleven ethers, nine gas-oxygens and one procain. The patient operated on under local anesthesia (Case 16) was a bad risk, aged 70, septic and uremic. Immediate relief was indicated; local anesthesia and every precaution against a threatening pulmonary disability were used, but to no avail. The condition was almost terminal.

The patients operated on under gas-oxygen (Cases 7, 10, 11, 12, 14, 17, 18, 19 and 20) again reflect our preoperative study of the cases, and that we recognize the necessity of protecting certain types of patients from the very complications under discussion. In all these cases except Case 11, there were present factors leading us to consider the patients poor operative risks. Cases 7, 10, 17 and 18 showed a definite preexisting lung condition. In Case 12, there was a septic focus in a man, aged 60; in Case 14 there was adenopapilloma of the stomach in a man, aged 52; Case 19 was bilateral hernia in a man, aged 65; in Case 20 the patient, aged 69, had varicose veins; in Case 11, the patient, aged 46, had hypertrophy of the prostate. The ages in all the latter cases were above the good risk age; Case 12 was distinctly septic; Case 14, a patient, aged 52, in whom an epigastric incision was necessary for cancer, cannot be considered a safe normal risk, and in Cases 19 and 20 the age, the rather protracted

TABLE 6.—Bronchitis

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	10033 E. V. Y. ♀, 29 February	Cholelithiasis	Well developed and moderately well nourished; weight 117 pounds, average 135; teeth poor; history of pleurisy, influenza, chronic tonsillitis, palpitation; blood pressure 110/60; heart negative; lungs, harsh breath sounds and a few loud squeaking râles at right apex	Cholecystectomy, appendicectomy, incidental, drainage Supine position	Ether (drop) 5½ ounces; anesthesia, 1 hour 10 minutes; operation, 1 hour 10 minutes; quiet throughout	Good recovery; 2d day after operation, temperature 100.6 F., pulse 110, respirations 26, slight cough, mucoid sputum; afternoon temperature 99.6 to 100 F., continued to 9th day; cough, numerous râles, both lungs; pain on deep inspiration on left side; discharged well, 17th day after operation
2	10111 M. E. C. ♀, 45 March	Fibromyoma of uterus	Well developed and nourished; colored; weight 112 pounds; history of dyspnea and palpitation, pneumonia three times (last 15 months before), precordial pain; lungs, moderate dulness both apices, few crackling râles; heart markedly dilated, systolic murmur; blood pressure 180/110	Supravaginal hysterectomy, bilateral salpingectomy, right oophorectomy, appendicectomy, incidental Trendelenburg position	Ether (drop) 6 ounces; anesthesia, 1 hour 15 minutes; operation, 1 hour 15 minutes; quiet anesthesia, pulse very rapid	Stormy recovery; following day, temperature 100.6 F., pulse 140, respirations 40; extensive râles, right back; gradual general improvement; afternoon temperature 100 to 101 F. until 12th day; discharged well but weak, 32d day
3	10201 S. R. ♂, 45 March	Acute cholecystitis	Well developed and nourished; rather obese; 207 pounds; heart, systolic murmur; lungs, a few râles, both bases, on inspiration	Cholecystectomy, drainage Supine position	Ether (Connell); anesthesia, 1 hour 55 minutes; operation 2 hours; difficult anesthesia, subcyanotic	Good recovery; 24 hours later, temperature 100 F., pulse 100, respirations 28; cough 4th day, temperature 99.4 F.; 10th day, temperature 101.4 F.; normal next day; discharged well, 20th day
4	10233 J. F. D. ♂, 19 April	Bilateral inguinal hernia	Well developed and nourished; 132 pounds; heart and lungs negative; blood pressure 106/74	Repair ..... Supine position	Ether (drop) 6 ounces; anesthesia, 1 hour 15 minutes; operation, 1 hour 5 minutes; well taken	Good recovery; 2d day after operation, temperature 101.4 F., pulse 100, respirations 40; cough; respiratory sounds distant and faint; voice sounds decreased; very small, questionable râles lower left back; 3d day after operation, temperature 99.6 F., pulse 80, respirations 14; discharged well, 19th day
5	10288 E. F. F. ♀, 55 April	Fibromyoma of uterus (malignant degeneration); general abdominal sarcomatosis	Well developed and nourished; 178 pounds; heart and lungs negative; blood pressure, 160/98; white blood cells 22,000	Supravaginal hysterectomy, bilateral salpingectomy, left oophorectomy; appendicectomy, incidental Trendelenburg position	Ether (drop) ?; anesthesia, 1 hour 45 minutes; operation, 1 hour 20 minutes; quiet throughout	Good recovery; following day mucus in throat, moist râles, both chests; temperature 100.6 F., pulse 110, respirations 36, 3d day; temperature 99 F., pulse 100, respirations 26, 5th day; lungs clear; discharged improved, 20th day

6	10333 H. E. T. ♂, 21 April	Appendicitis, subacute	Well developed and nourished; 107 pounds (125 pounds three months before); lungs negative; heart, systolic murmur (blowing); blood pressure 134/94; temperature 99.2 F.; white blood cells 12,000	Appendicectomy ..... Supine position	Ether (drop) 5 ounces; anesthesia; operation; quiet anesthesia	Good recovery; at 8 p. m., temperature 103 F., pulse 90, respirations 24; 12 hours later normal; 100 at 4 p. m., "slight bronchitis" noted; temperature remained normal after 3d day; discharged well, 16th day
7	10430 J. C. ♂, 27 May	Appendicitis, acute	Well developed, thin; lungs negative; heart, systolic murmur; history of pneumonia, lobar, 1914; teeth poor; blood pressure 154/90	Appendicectomy, drainage Supine position	Ether (drop) 8 ounces; anesthesia, 50 minutes; operation, 50 minutes; unsatisfactory anesthesia; pulse and respiration rapid, subcyanotic, much mucus	Good recovery; cough; squeaks and groans on expiration, both backs; temperature, pulse and respiration moderately elevated, normal 7th day; discharged well, 17th day
8	10710 K. W. ♀, 40 June	Pyosalpinx tubo-ovarian abscess	Well developed and nourished; obese; 143 pounds; heart, systolic murmur; lungs negative; history of fracture of several ribs 14 years ago, frequent pain in chest at site of above; blood pressure 110/70	Dilatation and curettage; bilateral salpingectomy, left oophorectomy, incidental appendicectomy, drainage Lithotomy and Trendelenburg positions	Ether (drop) 6 ounces; anesthesia, 50 minutes; operation, 1 hour 25 minutes; poor anesthesia, cyanotic, vomited once	Good recovery; following day cough, mucous sputum; temperature 101 F. (lower than before operation), respirations averaged 32 (24 preoperatively); discharged well, 23d day
9	10734 F. H. ♂, 32 June	Inguinal hernia, recurrent, left, strangulated	Well developed and nourished; 155 pounds; (emergency operation, history taken 9 days later); heart negative; blood pressure 106/68; lungs, coarse râles, both bases, on inspiration, frequent coryza	Repair ..... Supine position	Gas-oxygen; anesthesia 1 hour 15 minutes; operation, 1 hour; vomited food twice during induction, otherwise quiet	Good recovery; 24 hours later, temperature 103 F., pulse 120, respirations 30; cough; examination of chest—acute bronchitis, laryngitis; 2d and 3d days, temperature 101 F., pulse 100, respirations 30; 4th and 5th days, temperature 99.4 F.; 6th day 101 F., thereafter normal; discharged well, 26th day
10	10945 O. S. B. ♂, 43 August	Hydrocele, left	Well developed and nourished; 140 pounds; heart and lungs negative; blood pressure 130/70; history of pneumonia 12 years before; slight morning cough; teeth poor	Radical cure ..... Supine position	Gas-oxygen, very little ether; anesthesia, 55 minutes; operation, 45 minutes; quiet throughout	Good recovery; following day, temperature 101.4 F., pulse 108, respirations 36; infrequent cough; slightly diminished breath sounds over angle of scapula, impaired resonance left base 3d day; temperature normal; discharged well, 8th day
11	11298 N. R. ♂, 44 October	Inguinal hernia, right, recurrent	Small, undernourished; heart negative; blood pressure 100/60; lungs, impairment to percussion note at right apex, few râles on left; productive cough present; teeth poor	Repair ..... Supine position	Gas-oxygen, a little ether; anesthesia, 1 hour 20 minutes; operation, 1 hour 10 minutes; well taken	Good recovery; following day, temperature 101.4 F., pulse 108, respirations 34; numerous coarse bubbling râles, both lungs, back and apices, productive cough; temperature normal 7th day; discharged well, 20th day
12	11337 C. M. C. ♂, 40 October	Cholelithiasis	Well developed and nourished; obese; heart and lungs negative; operation postponed 10 days before for bronchial cough	Cholecystectomy, choledochostomy; drainage; appendicectomy Supine position	Ether (drop) 15 ounces; anesthesia, 2 hours 30 minutes; operation, 2 hours 25 minutes; difficult anesthesia, some cyanosis	Poor recovery, dyspneic, cyanotic; pulse and respirations rapid; following day, temperature 100.8 F., pulse 160, respirations 60; cough, many râles, both lungs; same night pulse dropped to 120, respiration to 38; general improvement; discharged well, 28th day

TABLE 6.—BRONCHITIS—*Continued*

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
13	11496 L. R. ♂, 39 November	Cholecystitis, chronic	Well developed and nourished; 170 pounds; heart and lungs negative; history of pleuritic pains in chest, frequent colds with considerable dirty yellow sputum; teeth poor; blood pressure 100/60	Cholecystectomy ..... Supine position	Gas-oxygen, ether (mask); anesthesia, 1 hour 20 minutes; operation, 1 hour 20 minutes; difficult anesthesia	Stormy recovery, much vomiting; 24 hours later, difficulty in breathing, slight cyanosis, diffuse bronchitis, cough, sputum (profuse); temperature 101.4 F., pulse 112, respirations 40; temperature dropped by lysis to normal 7th day after operation; discharged well, 24th day
14	11637 C. N. ♂, 63 December	Duodenal ulcer	Well developed and nourished; 148 pounds; heart and lungs negative; blood pressure 160/80; teeth poor; history of colds, occasional cough with thick yellowish sputum	Gastro-enterostomy, enfolding of pylorus Supine position	Procain, ether 5 ounces; ether anesthesia, 1 hour 5 minutes; operation, 1 hour 40 minutes; well taken	Good recovery; following day, temperature 98.8 F., pulse 104, respirations 35; dulness and crepitant râles, both chests; temperature 102 F., pulse 90, respirations 24 6th day; temperature dropped by lysis to normal 12th day; lungs clear 13th day; discharged improved, 32d day after operation
15	11000 J. C. ♂, 49 December	Inguinal hernia, left	Well developed and nourished; 173 pounds; heart and lungs negative; blood pressure 124/80; teeth poor	Repair ..... Supine position	Ether (drop) 8 ounces; anesthesia, 1 hour 15 minutes; operation 1 hour 5 minutes; fairly well taken, some coughing	Good recovery; 2d day after operation slight cough and pain in chest; temperature 99.8 F., pulse 96, respirations 24; following day, few moist sonorous râles at right back, cough less; discharged well, 17th day
16	11680 N. S. ♂, 57 December	Inguinal hernia, left	Well developed and nourished; 139 pounds (150 pounds a month ago); heart negative; lungs, slight relative dulness right apex, pharynx injected; slight head-cold and dry cough for 24 hours; blood pressure 125/75	Repair	Procain solution 1% (local); operation, 1 hour 5 minutes	Good recovery; slight coryza and cough; 3d day, temperature 100 F., moderate cough; two days later moderate râles, both chests, considerable cough and sputum; discharged well, 13th day
17	11720 M. M. ♀, 46 December	Myoma of uterus	Well developed and nourished; heart, systolic murmur; lungs negative; history of shortness of breath, dyspnea 12 years; pleuropneumonia at 24, epidemic influenza; palpitation, marked secondary anemia present; slight catarrh; blood pressure 112/60	Supravaginal hysterectomy; bilateral and salpingo-oophorectomy Trendelenburg position	Gas-oxygen, ether ½ ounce, procain; anesthesia, 1 hour 35 minutes; operation, 1 hour 15 minutes; quiet throughout	Stormy recovery; for three days after operation, afternoon temperature 101 F., pulse 120, respirations 25; temperature 100.5 F. in afternoon for next four days; 6th day after operation, examination of lungs—few gurgling râles and comparative dulness at right base; discharged well, 17th day

operation and the known incidence of embolism in such cases made them unusual. Case 11 alone appeared a good normal risk, and why the patient should have developed a complication is a little difficult to see. This patient showed an immediate onset of symptoms, the anesthetic was well taken, the recovery from it uncomplicated and the onset of the pathologic pulmonary condition remains unexplained. It is just such cases that bring most light to this subject for the general factors of anesthesia, pulmonary disease, etc., are lacking, and we believe that embolism alone gives such explanation.

In Cases 1, 2, 3, 4, 5, 6, 8, 9, 13, 15 and 21, ether anesthesia was used. In Cases 3, 4, 8, 13 and 15 there was either a definite lung disorder at the time of operation or a history of susceptibility to pulmonary trouble so definite that we should have taken warning. Cases 1 and 19 were both cases of ruptured appendix; the patients were very sick on admission, developed pneumonia almost immediately, and both died. The pneumonia revealed at necropsy was widespread. There was nothing unusual about the anesthesia, the amounts given were not large and the recovery in Case 1 was good and in Case 9 was stormy. The latter patient died in six days, and the former on the twenty-second day. In Case 1 there probably was a reinfection as the acute symptoms subsided after a week, only to recur with definite pulmonary signs four days before death. Cases 5 and 6 were rather frail appearing women subjected to pelvic operations in the Trendelenburg position. They each were given 7 ounces of ether, which was well taken, the operations lasting about one and one-fourth hours. In Case 6 there was a good recovery, in Case 5 a stormy recovery, the signs of pneumonia became evident between twenty-four and forty-eight hours but reached a maximum only on the third or fourth days. In Case 21, the patient was not considered a good risk, but had withstood cholecystectomy within a year without definite trouble so that the fatal pneumonia was a real calamity. The explanation, however, of the complication lies probably in the operation. For three hours, the patient was kept in marked Trendelenburg position. Otherwise, there was nothing unusual—7 ounces of ether, well taken, and good immediate recovery; but within twenty-four hours signs and symptoms of pneumonia appeared. Death occurred in forty-eight hours; pneumonia was certified at necropsy.

The study of this group of cases yields much of interest: first, that patients with an existing pathologic condition of the lung are susceptible to pneumonia if given ether; secondly, that intra-abdominal sepsis, as ruptured appendixes, or the Trendelenburg position are also contributing factors in the incidence of postoperative pulmonary complications. We can find, however, no cases in our series with the exception of Case 11, spoken of above, in which the anesthetic can

in any way be held to be alone or even to the greater extent responsible for the postoperative pathologic condition of the lung. There are other and more definite reasons present, often and usually in conjunction. One of these is an already existing pulmonary disorder evidenced either in the physical examination or in the history; another is the presence of sepsis, and still another the generally recognized fact that in laparotomies and especially in cases in which the operation is in the epigastrium, the danger of extension of infection or the sending off of small emboli from the operative field is very easy through the blood vessels or lymphatic channels.

Bronchitis.—In this class (Table 6), we had seventeen cases, 30.9 per cent., of the postoperative morbidity. The frequency of the condition is next to that of the pneumonias, but its absence of mortality makes its relative importance far less. However, a study of the factors in the causation of this complication brings out the same findings as previously stated under the pneumonias, and only tends to point the lessons we can learn more sharply. Of the seventeen cases, six patients were severely sick with prostration, great dyspnea, cyanosis and much mucus. Nine patients showed a preoperative lung disorder or gave a history of chronic pulmonary trouble. The average age was 40 years. All cases but one were laparotomies, and five were epigastric operations. Twelve patients were given ether, four gas-oxygen and one procain.

Definite criteria were taken in order to classify a case as bronchitis—râles, sputum and an accompanying general reaction giving a rise in pulse, temperature and respirations, and lasting over a sufficient number of days, at least three, in order that accessory and conflicting conditions might be ruled out. The fact that many of these patients were very ill with high pulse, temperature and respirations, râles, often pain, blood tinged sputum made the differential diagnosis from pneumonia difficult, but we accept as pneumonia only those cases with definite signs of consolidation. On the other hand, we may have missed a few very mild cases on which the postoperative notes left out certain findings thought unimportant.

The duration of the disorder varied from three days to two weeks. At the onset, there was often much cyanosis and excessive expectoration, often with the chest full of wet, noisy râles. The onset in all cases was within forty-eight hours, and subsidence occurred by lysis. The fact that all cases but one were laparotomies and in a high percentage of these there was an epigastric incision is in conformity with the universally accepted opinion that the incidence of postoperative pulmonary complications is higher in such cases, probably because of the free lymphatic connection between upper abdomen

TABLE 7.—PLEURISY

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9871 I. C. ♀, 46 January	Cholelithiasis	Well developed and nourished; 175 pounds; heart and kidneys normal; blood pressure 185/105	Cholecystectomy, appendicectomy, drainage Slightly reversed Trendelenburg position	Ether (drop) 7 ounces; anesthesia, 1 hour 30 minutes; operation, 1 hour 30 minutes; quiet throughout	Good recovery but some nausea and vomiting; seven days after operation pain on respiration, right chest; 9th day friction rub right axilla, relieved by strapping; no cough, lungs otherwise negative; slight postoperative rise in pulse, temperature and respiration for three days; normal by time friction rub was made out; discharged well, 23d day after operation
2	11657 N. S. ♂, 49 December	Duodenal ulcer	Sallow, fairly well nourished; 122 pounds; blood pressure 110/72; alcoholic; long history of gastric trouble; teeth carious, no outstanding cardiorespiratory symptoms or signs	Posterior gastro-enterostomy; plication of pylorus Supine position	Gas oxygen, procain; anesthesia, 1 hour 40 minutes; operation, 1 hour 25 minutes	Good recovery; no rise in temperature, pulse or respiration; uneventful convalescence until 20 days after operation, complaint of occasional discomfort in right chest led to examination and finding of occasional friction rub and relative dulness with rare râle at right base; discharged well, 27th day after operation

and root of lung. The high occurrence among herniotomies, five cases in seventeen, is striking, and though difficult to explain, is a finding reported not infrequently in the literature, even with local anesthesia. In our series, three of the five patients with hernia had a preexisting lung condition; of these, one was operated on under procain, the other two under gas-oxygen. It may be that the high incidence of pulmonary complications with herniotomies is due to the fact that the pampiniform plexus is a very thin-walled structure, easily traumatized and, therefore, the seat of fine thrombi which later reach the lung, or, and we are afraid this is often the case, the patients with hernia are given to the junior members of the staff for operation and therefore subjected to less experienced operators.

Although we have laid much stress on the presence of an already existing pathologic condition of the lung, we have also found a few patients with quite evident bronchitis who went through operation under gas-oxygen or procain without the slightest exacerbation in the pulmonary signs. This is important, as it makes the factor of small emboli assume greater proportions.

Pleurisy.—Two patients developed pleurisy, both of a very mild type, one on the ninth day and one on the twentieth day (Table 7). Both patients had pain on respiration followed by a friction rub, and one, Case 2, developed signs of fluid at the base where the rub had been heard. Both patients had epigastric incisions, but were considered good risks and did not have a preexisting lung condition. It is our impression that these lesions are due to fine emboli, sterile, which stick in the capillaries close to the visceral pleura, the anesthetic playing no part. Now and then, when such emboli come from a septic field, small peripheral abscesses form, break down, and we have a suppurative pleurisy if it is close to the pleura, or a lung abscess if it is in the substance of the lung.

Lung Abscess.—The two cases in this class (Table 8) are entirely divergent in type and etiology. In Case 1 the patient recovered, a good risk with a subdiaphragmatic abscess following appendicectomy, later a sterile pleurisy by direct irritation and still later a small intrapulmonary abscess apparently embolic in origin which was cured spontaneously by evacuation via the bronchi and trachea. The other case was fatal, and the condition almost terminal. The case was a bad risk in an old patient with chronic urinary stasis and many operations. The risk was recognized and gas-oxygen or procain used, but in spite of this, the foci in the lungs steadily became more outspoken and either through embolism or bronchial stasis, lung tissue itself became involved and an abscess in addition to a diffuse severe bronchitic condition was present at necropsy.

TABLE 8.—LUNG ABSCESS

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9962 H. B. S. ♂, 31 February	(1) Appendicitis, acute; (2) Subphrenic abscess, right	(1) Well developed and nourished; heart and lungs negative; white blood cells 16,000 (2) White blood cells 18,000; tenderness right costal border	Appendicectomy, drainage Supine position (2) Drainage Supine position	Ether (drop) 10 ounces; anesthesia, 55 minutes; operation, 50 minutes (2) Procain (local); operation, 30 minutes	Good recovery, no vomiting; 11 days postoperative thoracentesis, 300 c.c. straw colored fluid, culture sterile; temperature and pulse steadily rose; second operation 14th day; good recovery, but little change in temperature; dulness right chest persisted; three days following second operation, thoracentesis repeated with removal of straw colored fluid; roentgen-ray examination unsatisfactory; medical consultation—dulness at left base, voice sounds and breath sounds diminished except small area at angle of scapula where bronchophony and distant bronchial breathing heard anteriorly, a friction rub below the right nipple; diagnosis—lung abscess plus some fluid; 20th day after first operation patient coughed up large amount of foul, purulent material following which temperature, pulse and respiration came to normal within 24 hours and convalescence thereafter was uneventful; discharged well, 32d day
2	11584 H. L. 64 November	Stricture of urethra	Well developed and nourished (rare colds); lungs, rare râles, left back near angle of scapula and right base; 7 years of urinary difficulty; carious necrotic teeth; pulse 100	(1) External urethrotomy Lithotomy position (2) Suprapubic cystotomy, 2 drains Trendelenburg position (3) Placement catheter to bladder through perineal wound Lithotomy position	(1) Gas-oxygen; anesthesia, 1 hour 20 minutes; operation, 1 hour 10 minutes; quiet anesthesia (2) Gas-oxygen - ether; anesthesia, 1 hour; operation, 40 minutes; well taken (3) Procain (local); operation, 10 minutes	(1) Fair recovery; rise in temperature, pulse and respiration not marked; localized pain; second operation 48 hours later (2) Fair recovery; became weaker, diffuse râles in both chests, some dulness left chest anteriorly, 3d day; gradually better but continued to cough considerable purulent material; 14th day friction rub right base; quite suddenly 29 days after second operation developed septic tuberculosis with elevation of temperature, pulse and respiration, which continued to death 21 days later; with onset of this period bronchial breathing and râles appeared in entire left chest with cough; gradually the right lung also became involved in the same pneumonic process, sputum became purulent but not malodorous; death without marked change. Necropsy: pulmonary abscess right; bronchopneumonia; localized empyema, right; arteriosclerosis, etc.

TABLE 9.—EMPYEMA

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	10976 C. B. ♂, 35 August	Chondroma chest wall involving 2d, 3d and 4th ribs anteriorly, the size of an ostrich egg	Vigorous, well developed and nourished; 148 pounds; recently slight bronchitis; heart and lungs negative except for compression signs, right chest, below tumor; blood pressure 140/90; trachea, aorta and heart displaced to left	(1) Excision of tumor including 1st, 2d and 3d ribs (portions) anteriorly (2) Thoracostomy 13 days later; (trocar catheter method only, local anesthesia) for suppurative pleurisy.	Ether (Connell); intratracheal attempted but discarded; anesthesia, 4 hours 50 minutes; operation, 4 hours 15 minutes; perfectly smooth	Slow but satisfactory recovery from prolonged operation; steady daily rise in temperature, pulse and respirations; 3d day, temperature 106 F., pulse 150, respirations 40; thoracentesis at this time, serous fluid, apparently uninfected; white blood cells 6,400; condition slowly improved; temperature and pulse fell but breathing continued labored with expiratory grunt—40; white blood cells 15,000 5th day, evidence of harsh breath sounds and fine crackles at right axilla; coughing in paroxysms; on 12th day evidence of consolidation beneath the scapula, posteriorly, made out; bronchial breathing and râles; white blood cells 22,000; coughing increased when lying on right side and a foul expectoration brought up; condition critical 13th day, cyanotic, tracheal râles, sputum and breath odor of lung abscess; thoracentesis yielded purulent fluid; (2) under procain catheter inserted into chest through cannula (seropurulent fluid containing streptococci), prompt improvement, irrigation of chest, irrigating fluid tasted (evidence of bronchial fistula, presumably small lung abscess had ruptured into pleural cavity); steady, slow improvement, catheter connected with tube constantly immersed in saline, saline irrigation daily; cough cleared gradually; 40th day, roentgen ray (some cloudiness at right base and small area of pneumothorax about opening); 43d day up in chair; 46th day off constant drainage; rapid improvement; discharged well, 60th day, right lung clear both to physicial signs, auscultation and roentgen ray; 10 pounds only below weight on admission

Empyema.—The single case in this class (Table 9) was exceptional and followed direct operation involving the pleura itself. However, a close study would seem to show that probably the infection began as an intrapulmonary lesion. The patient was an excellent risk, but was subjected to a prolonged and dangerous operation. Intratracheal anesthesia (ether) was attempted but discarded, and the mechanical irritation at this stage may be blamed for the subsequent trouble. Immediately following operation, the temperature, pulse and respirations rose characteristic of pneumonia, and the signs of consolidation became evident a few days later in the right axilla. Aspiration yielded serous fluid on the third day after operation. The condition was stationary for a week; then about the twelfth day there was a rather sudden change for the worse, with cyanosis and marked pulmonary edema. The sputum became progressively more and more foul, almost suggesting gangrene of the lung. Drainage was established with a catheter, and there was rapid improvement; but irrigations with a surgical solution of chlorinated soda (Dakin's solution) revealed the presence of a bronchial fistula. The drainage was removed on the forty-sixth day, when the chest was almost entirely free of pathologic signs. The patient was discharged well on the sixtieth day.

Embolism.—In this class there were three cases and two fatalities. The fatalities were typical of this complication. Operations were on the kidney and prostate. Large thrombi must have formed in the great veins and slid off on the third or fourth day. There were no premonitory signs in Case 1, but in Case 3 the fatal onset was preceded for twelve hours by a local pain at the site of operation. The lesions were certified at necropsy. In Case 2 we anticipated an even more serious result, as operation had revealed large thrombi in old varicose veins. Apparently, a very small embolus was loosened on the twenty-third day followed by chest pain, chill, but no other pulmonary signs or symptoms. In our experience, the last type of case is always to be considered dangerous from the fear of this very complication.

In the group of pulmonary embolism (Table 10) are included cases in which a sudden pulmonary upset occurs owing to circulating thrombi wedging in large pulmonary vessels. As a rule, such cases are fatal and, although minute thrombi may and probably do occur in a majority of all postoperative pulmonary complications of whatever group, they are not classified under this heading but under the clinical condition they cause. The clinical picture of pulmonary embolism is too well known to need discussion.

Pulmonary Complications in Tuberculous Patients.—We believe that a study of this group of cases is of the greatest importance because careful selection of cases may prevent disaster and when complications

TABLE 10.—Pulmonary Embolism

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9738 W. C. S. ♂, 50 January	Pyonephrosis	Well developed and nourished; heart and lungs normal; blood pressure 138/88	Left nephrectomy, drainage Lumbar position	Gas-oxygen (very little ether); anesthesia, 1 hour 40 minutes; operation, 1 hour 30 minutes; quiet anesthesia	Good recovery; no appreciable elevation of temperature, pulse or respiration; 4th day after operation, sudden convulsive seizure, unconsciousness, jerky respirations, poor color, imperceptible pulse; momentary consciousness, vomiting, imperceptible pulse, great dyspnea, death. Necropsy: cardiac and pulmonary embolism, pyelitis, etc.
2	11075 J. A. M. ♀, 34 September	Thrombophlebitis, left, internal saphenous system	Well developed and nourished; 150 pounds; heart and lungs normal; blood pressure 110/60; severe sore throat and submaxillary glands, left, 2 weeks before; temperature 105 F.; pulse 130; respirations 40 on admission	Incision and drainage (in bed)	Gas oxygen; anesthesia, 15 minutes; operation, 10 minutes; well taken	Uneventful course following operation; T. remained septic but general condition satisfactory; suddenly, 23 days after operation, attacked with severe pain in the left lower chest anteriorly with chill, immediate rise of temperature, pulse and respiration and continued elevation of all for a period of three days from which time patient made a rapid and steady return to normal; at time of attack no change in chest symptoms, no cough; discharged well, 32d day after operation
3	10240 H. N. C. ♂, 65 April	Obstructing prostate (median bar)	Well developed and nourished; heart and lungs negative; blood pressure 104/64	Suprapubic partial prostatectomy, drainage Trendelenburg position	Gas-oxygen (very little ether); anesthesia, 45 minutes; operation, 35 minutes; well taken	Good recovery; convalescence uneventful until 3d day, when without warning several fleeting attacks of pain in pelvis occurred, increasing in severity; following last and most severe attack of pain patient unconscious and died in a few minutes. Necropsy: pulmonary embolism, thrombosis of veins; prostatic plexus, early cancer in bile passages, etc.

do ensue it may mean sanatoriums for life, whereas otherwise the lung disease might have remained quiescent for years. A good many patients with fairly quiescent pulmonary tuberculosis will appear yearly in any large clinic, and the cases we present are probably representative of most clinics in large cities. In the five cases summarized (Table 11), all the patients had either pulmonary signs or a history leading one to suspect tuberculosis. In Cases 1 and 2, the patients became progressively worse with marked pulmonary symptoms and were finally transferred to sanatoriums for further care. The other three patients after acute flare-ups recovered and were discharged with apparently inactive lesions and in about the same condition as on admission. In addition to these cases were found three other cases of pulmonary tuberculosis among those patients operated on in the year under discussion, all of whom showed no appreciable change and therefore are not counted as cases of postoperative pulmonary complications. The two patients that became worse were given ether, and it is fair to say that tuberculosis was absolutely unsuspected. In the other patient having ether (Case 4), we did not take much stock in his story as he was a particularly well developed man—a great mistake on our part. The other two patients and also the three mentioned as being unchanged by operation received gas-oxygen or procain, and it is our opinion that in this very field the added irritation of ether is a mistake. However, even here we must not be too sure of the part the anesthetic plays; for in the light of such a general study, the facts that in all cases sepsis was present and that the abdomen was the field of operation assume greater proportions.

Pulmonary Complications—Mistaken Diagnoses.—Among the cases of the year reviewed are found two patients, aged 13 and 45, with pneumonia operated on for appendicitis, in whom normal appendixes were found. Gas-oxygen anesthesia was used in both cases and recovery occurred by lysis in one case and crisis in the other. The definite signs and symptoms of lobar pneumonia, right side, were evident the day following operation. There need be no discussion of this, as it is simply an example of mistaken diagnosis, and we include the cases only to add weight to our underlying plea that the careful examination of lungs is one of the most important steps previous to any operation.

Empyema and Lung Abscess.—In a study such as this, we believe that patients suffering from and operated on for either empyema or lung abscess are not to be considered, since an increase in the amount of the lung disability is almost sure to occur. However, it is true that were such cases badly handled, operation performed under full ether anesthesia, etc., just criticism should fall on those responsibble.

TABLE 11.—EXACERBATION OF TUBERCULOSIS

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation; Position on Table	Anesthesia, Kind, Amount; Duration of Anesthesia; Duration of Operation	Postoperative Course, Pathology
1	9958 J. T. ♂, 20 February	Appendicitis, subacute	Fairly well developed and nourished; 115 pounds; heart and lungs negative; blood pressure 112/46; history of vomiting a "tumbler full of blood about every three months"	Appendicectomy (no drainage) Supine position	Ether (drop) 4 ounces; anesthesia, 40 minutes; operation, 40 minutes; quiet anesthesia	Good recovery; 2d day, pain in chest, right; examination negative but 3d day find râles, right base; steady rise in pulse, temperature and respirations; 5th day dulness, râles, bronchial breathing right lower back; signs later of fluid; roentgen ray 21st day; dulness right lower back with fluid here and mottling above this; 33d day, tuberculosis bacilli in sputum; temperature, pulse and respirations remain elevated. Medical consultation: acute tuberculosis; transferred 34th day to tuberculosis sanitarium
2	10550 F. H. G. ♂, 14 May	Tuberculous peritonitis (admission diagnosis, acute appendicitis)	Well developed and nourished; 130 pounds; heart normal; lungs negative; back not examined; white blood cells 14,000	Exploratory laparotomy Supine position Generalized tuberculous peritonitis found (no drainage)	Ether (drop) 6 ounces; anesthesia, 40 minutes; operation, 40 minutes; quiet, respirations and pulse rapid	Good recovery but running typical hectic chart; examination of chest 14th day; consolidation throughout right back with egophony and increase in tactile and vocal fremitus; white blood cells 15,000; diarrhea; discharged 30th day, with very active signs as in Case 1, to tuberculosis sanitarium
3	11478 B. S. ♀, 54 November	Ulcer of stomach (hour glass contraction)	Emaciated, 81 pounds; previous admission, diagnosis ulcer and ? of pulmonary tuberculosis refused operation; one child died of tuberculosis; for 2 years cough, sputum, blood, night sweats, dyspnea; mouth foul; heart normal; blood pressure 142/90; lungs, patches of dulness right lung, with bronchial breathing; no râles; roentgen ray of stomach, hour glass contraction, ulcer lesser curvature	Cauterization of ulcer; posterior gastro-enterostomy Supine position	Gas-oxygen (no ether); anesthesia, 2 hours 5 minutes; operation, 1 hour 45 minutes; quiet throughout	Good recovery; slow rise in pulse, temperature and respirations not marked; 5th day tubular breathing, left base, with râles; slight hemoptysis; white blood cells 17,000; respirations 35; dulness and tubular breathing disappeared in three days but râles remained; sputum consistently negative for tuberculosis but foul, little cough; 10th day signs of activity, front upper lobe which also disappeared in three to four days; discharged improved, 39th day
4	11109 H. W. ♂, 40 August	Appendicitis, acute	Well developed and nourished; 156 pounds; heart and lungs negative; white blood cells 17,000; temperature 101.2 F.; history of spitting up blood for a week 4 years before	Appendicectomy, drainage	Ether (drop) ?; anesthesia, 45 minutes; operation, 35 minutes; smooth anesthesia	Good recovery; slight rise of temperature, pulse and respirations; 12th day after operation some pain in right back on deep inspiration; small amount of blood stained sputum, small area of dulness extreme right base posteriorly with question of diminished breath sounds; next day definite dulness over right base, diminished breathing, vocal fremitus with occasional râles; thoracentesis, no fluid obtained; roentgen ray examination unsatisfactory; sputum negative for tuberculosis; 26th day, signs of consolidation right base with few râles; general condition entirely satisfactory; 28th day, roentgen ray, mottled areas right base and right apex; discharged 38th day, general condition excellent, but physical signs in chest persisting
5	11554 E. L. O. ♂, 33 November	No diagnosis (admisison diagnosis appendicitis)	Well developed and nourished; 130 pounds; heart normal; lungs negative; white blood cells 15,000; hacking cough (little sputum) for 9 years past; nasopharyngeal discharge; tonsils and pharynx red and injected; teeth carious; blood pressure 110/60; roentgen ray, very suggestive of tuberculosis right apex	Exploratory laparotomy; incidental appendicectomy Supine position	Gas-oxygen (no ether); anesthesia, 1 hour; operation, 50 minutes; well taken	Good recovery; slight gradual rise of temperature to 101 F. on the 5th day; 8th day, dulness right upper chest, front and back, profuse râles right lung; 15th day, temperature normal, lung clearing; sputum, no tuberculosis found; discharged in good condition 24th day after operation

There were thirteen patients with empyema and two patients with lung abscess submitted to operation in the series studied. Three patients were given gas-oxygen anesthesia, and all the others were operated on under procain. The two patients with lung abscess died; all of the patients with empyema recovered. There was in addition one patient with a mediastinal abscess following influenza with bronchopneumonia who, following incision and drainage under gas-oxygen, did well and was discharged in good condition.

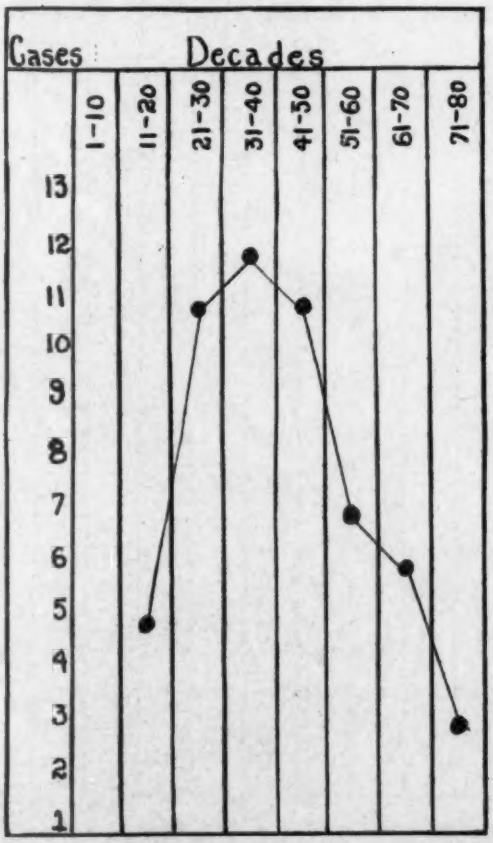

Chart 1.—Incidence of postoperative pulmonary complications by decades.

GENERAL DISCUSSION OF THE MATERIAL

Chart 1 shows the incidence of postoperative pulmonary complications by decades; Chart 2 the seasonal variation, and Table 12 the methods of anesthetization in this report in relation to the morbidity. Sixteen patients included in Chart 1 were more than 50 years of age, and twenty-seven were more than 40, bringing 50 per cent. of the cases into the later years of life and the proportion of post-

operative morbidity to a very high point among the aged and infirm. This is, however, no higher than figures by Osler and McCrae [19] for such cases in simple infectious pneumonia.

Chart 2 is not striking, but it does show an increased incidence in the colder months, which is in conformity with the findings in our previous investigation and with those of Whipple,[3] Armstrong,[8] Balfour [50] and other investigators.

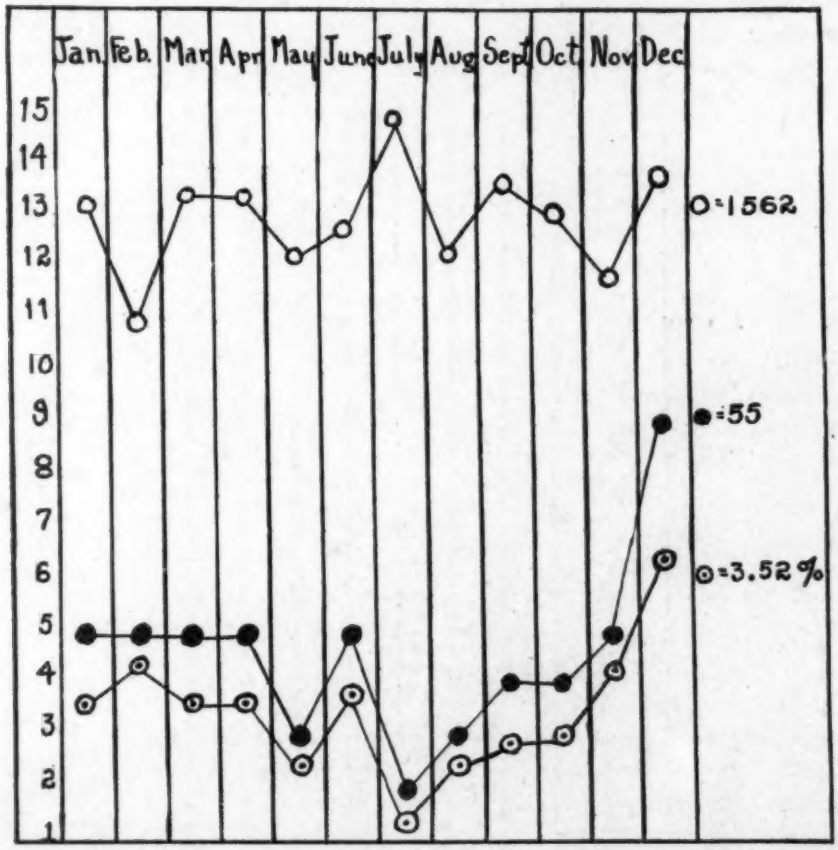

Chart 2.—Seasonal variations in postoperative pulmonary complications. open circle, number of operations per month, the number at the side should be multiplied by 10; solid circle, number of pulmonary complications per month; circle and dot, percentage of pulmonary complications per month.

Table 12 gives the number of complications occurring with the different anesthetics. Of the total 1,562 operations, 943 were performed under ether, 495 under gas-oxygen, 117 under procain, and two under chloroform and five with spinal anesthesia. This gives a

50. Balfour: Collected Papers Mayo Clinic, Philadelphia, W. B. Saunders Company, 1913, p. 743.

morbidity percentage of 3.39 for ether, 4.24 for gas-oxygen and 1.63 for procain. But we must know that the "bad risk" patients were given gas-oxygen; otherwise the higher figure for this group might be translated wrongly. However, these figures do as a whole support our belief that the rôle of the anesthetic is usually a minor factor. Otherwise, the proportion of complications under ether, which is certainly more irritant, would be higher. It is true that the incidence under procain is low; but, again, one must remember that operations under local anesthesia are performed gently and it is used only rarely in septic cases.

TABLE 12.—POSTOPERATIVE COMPLICATIONS FOLLOWING VARIOUS ANESTHETICS

Complication	Anesthetics				
	Ether	Gas-Oxygen-Ether	Gas-Oxygen	Procain	Totals
Lobar pneumonia	3	..	1	..	4
Bronchopneumonia	11	..	9	1	21
Bronchitis	11	1	4	1	17
Pleurisy	1	..	1	..	2
Empyema	1	..	..	..	1
Pulmonary embolus	..	..	3	..	3
Lung abscess	1	1	..	..	2
Exacerbation of tuberculosis	3	..	2	..	5
Totals	31	2	20	2	55

A discussion of the various methods of giving anesthesia we hardly think necessary, since such performances are now well standardized, and especially since we believe that the evidence is overwhelmingly in favor of other factors in the etiology. In this clinic, ether is given either by the open drop method using a Ferguson mask, or by the Connell ether machine and an intranasal tube. For gas-oxygen we use the Connell gas machine, using in addition to the basic gases, when necessary for relaxation or other causes, a few drops of ether. Procain, 1 per cent., is used for local anesthesia. Careful anesthesia charts are kept with records of pulse and respiratory rate every ten minutes or more frequently if necessary; blood pressure readings are kept during more serious operations and the time of beginning anesthesia, beginning of operation, closing of anesthesia and end of operation are carefully recorded. The anesthetists, in addition, record the amount of anesthesia, general reaction of the patient, and any further data which they may think of importance or use. Trained nurse anesthetists are employed in addition to the house officers to whom they give instruction, and the staff of this hospital believes that this is one of the most satisfactory elements in our operating room work. As a result of this study we have suggested that our anesthesia records be made more complete by recording on the back of the chart the bed-

side notes for the first twenty-four hours after operation. Patients in this hospital recover in special rooms under observation on the operating room floor, and every precaution is taken during and after operation to protect the patients from chilling and exposure. The only loophole of importance rests beyond such operative or postoperative care. It resides in the judgment of the surgeon as to when and how to operate, or rather when not to operate. There can be no shifting of this responsibility to the methods of anesthesia or to the after-care.

TABLE 13.—PULMONARY COMPLICATIONS

Complications	Number of Cases	Morbidity per Cent.	Number of Deaths	Mortality per Cent. of Morbidity	Approximate Morbidity per 100 Cases	Approximate Mortality per 100 Cases
Lobar pneumonia	4	0.25	0	0.0	1 in 391	0
Bronchopneumonia	21	1.34	8	38.0	1 in 74	1 in 195
Bronchitis	17	1.08	0	0.0	1 in 92	0
Pleurisy	2	0.12	0	0.0	1 in 781	0
Empyema	1	0.06	0	0.0	1 in 1562	0
Pulmonary embolism	3	0.19	2	66.6	1 in 521	1 in 781
Lung abscess	2	0.12	1	50.0	1 in 781	1 in 1562
Exacerbation of tuberculosis	5	0.32	0	0.0	1 in 312	0
Totals	55	3.52	11	20.0	1 in 284	1 in 142

Morbidity of pneumonia group to total operations, 1.6
Mortality of pneumonia to total operations 0.51

Table 13 depicts the seriousness of this problem and indicates in which group we shall find the fatalities. All investigations have revealed a very high incidence of pneumonia and, as we have discussed on an earlier page, the literature on postoperative pneumonia is by no means meager. Because this group carries such a serious result, we, too, have spent most time in its study. The opinions as to its etiology are often divergent, but may be roughtly divided into the embolic and irritative groups with the general factors of age, seasonal incidence, preexisting pulmonary disorder and sepsis as contributing factors. If these lesions were purely irritative, unquestionably the anesthetic must be at fault and improvements in the methods of anesthesia with absence of vomiting, decreased salivation and inhalation of mucus and the open drop method would have shown a marked reduction in this complication. Also, patients with a preexisting lung lesion would be almost certain to have a pulmonary complication. This is not the case. In spite of the writings of Magaw [47] and Henderson,[45] we submit that even with anesthesia in skilled hands, pneumonia claims a high morbidity. In 1916, in this hospital, the pulmonary complications reached 4.37 per cent., and they still remain at 3.52 per cent. in spite of the fact that the majority of all anesthesias are administered by highly trained people. Besides, there is much evidence on the other side. Primarily, pulmonary complications are

not infrequent under local anesthesia, they are also common under gas-oxygen anesthesia, they occur even when the anesthesia is administered by a skilled and highly trained anesthetist. Also they seem to be present in a more definite proportion to certain other factors. The chief of these is sepsis. The fact that all our fatalities occurred in patients either operated on for inflammatory lesions primarily, or in whom sepsis could have occurred as in intestinal operations, is strong evidence. Moreover, the reports of Ranzi,[9] Kelling,[18] Bibergeil [12] and Burnham [28] emphasize the importance of sepsis. We submit that the danger of sepsis lies in embolism, and that embolism is the chief source of pulmonary complications except in those patients already presenting definite pulmonary lesions. In using the term embolism, we include

TABLE 14.—Relation of Occurrence of Pulmonary Complications to Mobility of the Operative Field

Operative Field	Complications								
	Lobar Pneumonia	Bronchopneumonia	Bronchitis	Pleurisy	Empyema	Pulmonary Embolism	Lung Abscess	Exacerbation of Tuberculosis	Totals
Cranium	..	1	..	..	..	..	..	..	1
Thorax	..	..	..	..	1	..	..	..	1
Kidney	1	..	..	..	..	1	..	..	2
Upper abdomen	1	3	5	2	..	..	..	1	12
Lower abdomen:									
1. General	..	4	..	..	2	..	1	4	11
2. Inguinal hernia	1	5	5	..	..	..	..	..	11
Pelvis	1	3	4	..	..	..	..	..	8
Prostate (suprapubic)	..	2	..	..	..	1	..	..	3
Perineum	..	2	..	..	..	..	1	..	3
Scrotum	..	..	1	..	..	..	..	..	1
Lower extremity (varicose veins)	..	1	..	..	..	1	..	..	2
Totals	4	21	15	2	3	3	2	5	55

transmission by lymphatic channels as well as by the circulatory system. In patients with a preexisting pulmonary disorder, and they are sometimes overlooked even in the best clinics, a local increase in the already present condition by direct extension may be the etiologic source. If we accept the findings of Whipple [3] and Stillman [20] as to pneumococcus carriers, the mechanism is easy to understand. In our first study in 1916,[2] we, too, took this attitude and felt that although the anesthetic was not the chief factor the etiology lay in its irritant action on an already existing, though possibly quiescent, lung disorder. A more careful study such as this, possibly because of more complete and accurate data, has shown us that this alone does not explain the situation. Too many patients develop a complication without any preexisting lung disorder, either under perfect anesthesia conditions or under local anesthesia. As evidence to support our contention in regard to

embolism, we have the fact that fatal pulmonary embolism does occur and is easily recognized pathologically. Moreover, it may occur early. In this study, the two fatal cases occurred on the third and fourth days. Further evidence as to the part sepsis plays in this lesion is not necessary (Kelly,[51] Ranzi,[9] and McCann [52]). The setting free of such emboli depends: (1) on sepsis, and (2) on the mobility of the part. The latter factor is recognized by other observers, and further proof is shown by the higher incidence of pulmonary complications in parts of the body which cannot be kept at rest. Table 14 shows strikingly the relation of the mobility of the part to the occurrence of pulmonary complications.

Thus, approximately 2 per cent. of all patients operated on develop a pulmonary complication; when the field is confined to the abdomen the incidence rises to 4 per cent., while in 8 per cent. of epigastric operations some one of the lung complications develops. Moreover, in cranial operations such lesions are rare. Why? Because in the last class there is perfect splinting of the tissues from the underlying bone, whereas in the other groups mentioned mobility of the part rises with the increasing incidence. In the epigastrium each breath pulls on the wound, and no matter how gentle the surgeon, or how accurate his approximation, small thrombi will in time be loosened and showered into the lung. If sepsis is present, and this occurs at once because of manipulation, a pulmonary complication is assured. Moreover, in these very cases we have direct lymph drainage and also hypostasis, the latter increased (1) by the dressings, and (2) by the effort of the body itself to splint the part. We do not think the fact that the complications as a rule appear shortly after the operation is evidence against embolism, and for the irritant effect of the anesthetic. In this study, forty-two patients (76.4 per cent.) showed signs and symptoms within forty-eight hours. Certainly, the manipulation on the table would be greater than any subsequent mobility, and doubtless many fine thrombi are set free at this time. The fact that the majority of such patients were operated on for septic lesions makes these emboli only the more dangerous; and if a preexisting lung lesion is present in addition, the danger of an ensuing complication is increased. A study of the operators throws some light on these facts. The men considered as gentle slow operators have a proportionately lower morbidity, which we consider to be an added reason for the embolic theory. These men, though subjecting their patients to a longer operation, cause less trauma and therefore cause less thrombosis.

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51. Kelly: Brit. M. J. **2**:17, 1912.
52. McCann, F. J.: Brit. M. J. **1**:277 (March 9) 1918.

Having established in our own minds that embolism is the chief factor at work, we must confess that there are often other factors of varying importance. Thus, the part which a preexisting lung lesion plays is often considerable. In twenty-two of the fifty-five cases, in addition to the five tuberculosis cases there was given by history or physical signs, evidence of a preoperative pulmonary disease. At the time of operation, these findings were not seriously considered, but in a careful postoperative study their importance is indicated. It was this finding which in the first study by one of us in 1916 in collaboration with Morton,[2] made us feel that the eradication of this difficulty lay in a more careful preoperative study of the lungs. Whipple [3] reported a preexisting lung lesion in twenty-five out of the ninety-seven complications in his series. Others may not have been noticed. In the light of the present study the importance of this factor cannot be overestimated, since if we have an already subacute lung lesion and shower into it fine emboli, even if they are not septic, they will cause sufficient circulatory and pressure disturbance to cause the existing latent process to flare up. It is certainly the latter group in which the anesthetic might have considerable effect; and if the patient is already a pneumococcus carrier, the conditions for infection are fulfilled. Here such a thing as an irritative pneumonia or bronchitis might result. If it did, it would presumably be a local affair, and therefore lobar in type. But lobar pneumonia is rare in comparison, and, indeed, the four patients in this study might possibly have had some process in both lungs had our use of the stethoscope been more experienced. All fatalities showed bronchopneumonia. Moreover, most of the bronchitis cases were of the sudden, acute, bilateral type. The explanation of this group we believe is either irritation on top of a preexisting lung disorder or fine aseptic emboli showered in from the operative field.

Beyond these three chief factors lie other predisposing and accessory factors, as the general state of the patient, his age, appearance and cardiorenal condition. We know that ether produces an acidosis (Frank [53]). Does the circulation back down during operation, giving poor lung circulation and a favorable field for organisms already present (Whipple [3])? How much does this acidosis lower the general resistance? Hamburger [54] of Gröningen has shown that if marked it reduces the phagocytic power of the leukocyte. We know that only 40 per cent. of our patients were at an age when the risk begins to be considered serious. Of the fifty-five cases reported, thirteen can be called good risks, twenty-nine fair, and only thirteen poor risks.

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53. Frank, L.: Surg., Gynec. & Obst. **30**:185 (Feb.) 1920.
54. Hamburger, H. J.: Brit. M. J. **1**:37 (Jan. 8) 1916.

We agree, of course, that a poorly administered ether anesthesia with a wet, blue patient, who vomits during the induction or constantly inhales mucus, may be the direct cause of a pulmonary complication; but this does not explain the great group of such cases. Possibly chilling, too, plays a rôle, whether it is exposure in the preparation (Homans,[26] Keen,[35] McKesson [55] and Kelling [18]) or chilling of the body cavities with cold packs (Armstrong,[8] Kelling,[18] Bibergeil [12]) or exposure after operation. Curiously, males are more susceptible than females, and it has been suggested that this is again a vasomotor factor, in that men are accustomed to wearing heavy underclothes, and that the change to thin hospital nightgowns is a greater exposure to them. There is one other factor about which there has been much dispute. Hoelscher [32] and Kelly [51] demonstrated experimentally the aspiration of mucus during anesthetization, and there has been much written about the rôle of oral sepsis (Turner [56]). We can only say that in our experience this factor is of minor importance. The type of patient admitted to the public wards of this hospital exhibits often poor teeth which may be necrotic and carious with much pyorrhea. If oral sepsis was a dominating factor, we should expect a far higher incidence, whereas patients with clean mouths often develop these complications.

SUMMARY AND CONCLUSIONS

Postoperative pulmonary complications constitute a serious menace to any patient who submits to operation. Reliable statistics show that one patient in from every thirty to fifty patients operated on, no matter what the anesthetic, develops a pulmonary complication, and one patient in from every 150 to 175 patients dies from some such complication. The factors responsible for this are complicated and not always preventable, but an understanding of the mechanism suggests prophylactic measures.

We believe that embolism from the operative field is the chief factor in the etiology of such complications. It is favored by: (1) sepsis, (2) trauma, and (3) the mobility of the part. Other factors of varying importance are preexisting lung disease, the irritation of the anesthetic and such general factors as old age, chilling and poor general condition. Such embolism may occur immediately during the operation or during the convalescence, and may be the cause equally of pneumonia, bronchitis, pleurisy, empyema, lung abscess or fatal pulmonary embolism. Embolism in the sense we use it includes the transfer of small particles which may or may not be sterile from the

55. McKesson, E. I.: Am. J. S. (Anesthesia supp.) **32**:16 (Jan.) 1918.
56. Turner: Proc. Roy. Soc. Med., 1912-1913, Odontological Sec., 79.

operative field to the lungs by either the lymphatics or blood channels. We do not presume to state that this is the sole cause or always the chief etiologic factor. And in accord with the previous study of one of us [2] and the reports by Whipple,[3] we believe that inhalation anesthesia on top of an existing lung lesion may in some cases be the dominant factor.

The following prophylactic measures are suggested: (1) a reduction in operative trauma in an effort to produce as few and small thrombi as possible; (2) every effort in septic cases to prevent further extension of infection so that bacteria will not be present in the blood stream, nor sepsis aid in the setting free of thrombi; (3) to avoid, if possible, operating on patients with an existing lung lesion, however slight; (4) avoidance of chilling both by cold packs in laparotomies or by widely gaping wounds and by exposure after operation, and (5) to make each case before operation as good a risk as that individual case can be made.[57]

Undoubtedly, all surgeons try to carry out these obvious prophylactic measures. There is evidence that pulmonary complications follow even the simplest operations in the best hands, but the weight of evidence is overwhelming that serious pulmonary complications can be prevented to a large extent if such measures are appreciated and carried out in detail.

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57. In addition to the references already given, the following will be found of interest:

Birtch, F. W.: California State J. M. **16**:200 (April) 1918.
Gerulanos: Deutsch. Ztschr. f. Chir. **57**:382.
Henle: Arch. f. klin. Chir. **64**:339, 1901.
Robb and Dittrick: Surg., Gynec. & Obst. **3**:51, 1906.

THE SECOND GREAT TYPE OF CHRONIC ARTHRITIS

A LABORATORY AND CLINICAL STUDY *

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SAN FRANCISCO

Under this head, I include the cases described under many different names and by numerous writers, e. g., arthritis deformans (German), osteo-arthritis (English), hypertrophic arthritis (Goldthwait), degenerative arthritis (Nichols and Richardson). This is the so-called senile form of arthritis, the "chronic rheumatism" of the elderly, the metabolic form of arthritis. Other writers have employed other terms, almost without number.

The subject is a most confused one, so confused that, in reading an article, one is often at a loss to understand the author's meaning, whether he is really discussing this disease or one entirely different.

Generally, the name employed is one that describes the characteristic which the author deemed most important, but it often turns out to be a misnomer in the light of subsequent investigation, and is thus a source of confusion. Thus "arthritis deformans," a mixture of Greek and Latin, means different things to different people.[1] Again, any severe joint inflammation may be a deforming one. Osteo-arthritis means simply an inflammation of bone and joint. Hypertrophic arthritis describes well the most prominent feature of the roentgenogram, but, as I shall attempt to show, and as others before me have indicated, bone atrophy far exceeds bone hypertrophy in this disease, and is really its characteristic pathologic feature.

The term degenerative arthritis was chosen because the originators of the term considered the degeneration of the cartilage to be the primary change, whereas it is almost undoubtedly the result of changes deep in the bone. Senile arthritis would usually apply, but the disease occasionally occurs as early as the third decade. The term "metabolic arthritis" means nothing at all.

Eventually, our classification of the arthritides will probably be on an etiologic basis exclusively, but our knowledge at present does not suffice for this, and in the meantime it is well to adopt a nomenclature that will prevent confusion.

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* From the Leland Stanford Junior University Clinics and Laboratory of Surgical Pathology.

1. Byfield, A. H.: The Etiology of Arthritis Deformans in Children, Am. J. Dis. Child. **19**:87 (Feb.) 1920. The author evidently is discussing a disease entirely different from that originally described as arthritis deformans.

All cases of chronic arthritis fall naturally into two classes, or types: those which do not show spurring at the lines of insertion of the capsule, and "lipping" at the circumference of the articular cartilage, and those which do show this spurring and lipping. The first type includes tuberculous, gonorrheal, syphilitic, typhoid, diplostreptococcic joints, etc. The second includes the joints under discussion. Tabetic joints are not included.

My clinical material consists of the ninety patients whose histories are abstracted here, who were seen during the last five years at the Stanford clinics.

Fig. 1.—The lower end of two dried femurs, showing typical lipping at the joint circumference.

The diagnosis was made tentatively by clinical examination, and was established by the roentgen rays. If the roentgenogram showed bony spurs or "lipping" of the joint, the case was included in the list; if it did not, the case was thrown out. Positive evidence of bone formation at the joint line was the criterion (Fig. 1).

My pathologic material consists of fragments removed from many joints at operation, and of four femoral heads and one knee joint gained by resection, and described herewith. These were fixed in liquor formaldehydi or alcohol and sections were carefully made. Sec-

tions were decalcified in 5 per cent. nitric acid, run through the alcohols and ether, embedded in celloidin or a substitute, cut with a microtome, stained with hematoxylin and eosin, and with the van Gieson, Giemsa and Gram-Weigert stains. Specimens 225, 227 and 229 were taken immediately after removal at operation to the bacteriologic laboratory for investigation,[2] and cultures were made from them forthwith, that is, within ten minutes after removal.

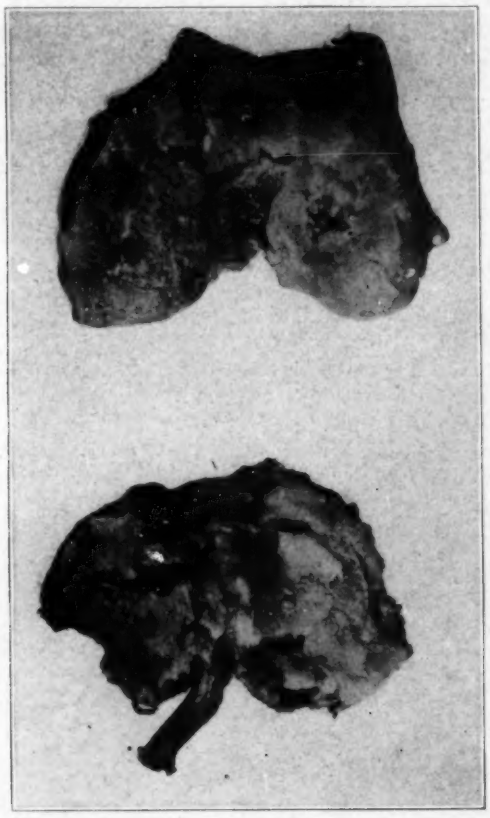

Fig. 2.—Typical joint surfaces in second type of arthritis; distal end of femur and proximal end of tibia.

PATHOLOGY

The joint changes of this type of arthritis have been well described, especially by Nichols and Richardson.[3]

The gross changes are: cartilaginous and bony lipping at the circumference of the joint, with bony spurs at points of insertion of the

2. The bacteriologic work was done in the bacteriologic laboratory of the Leland Stanford Junior University School of Medicine.

3. Nichols and Richardson: Jour. Med. Research **21**:150, 1909.

capsule; thickening of the cartilage, then calcification and erosion, leaving the underlying bone bare; condensation of this bone (eburnation) with grooving in the line of joint motion; hypertrophy of the synovial membrane, with marked villous formation, and frequently fluid in the joint.

Adhesions between the bone ends never result from these changes, as they do in the first type of arthritis (tuberculous, syphilitic, gonorrheal, etc.), and the limitation of motion is caused solely by distortion of the ends of the bones. (The bony ankylosis in the spine forms an exception to this rule.) The joint is mechanically damaged.

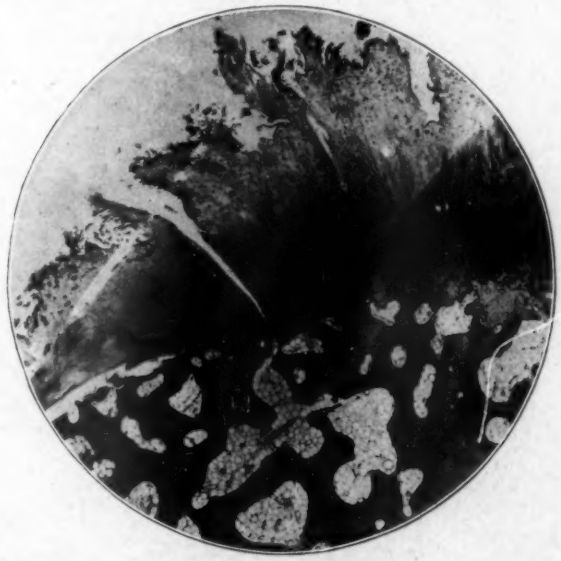

Fig. 3.—Low power photomicrograph of stained section, showing typical fibrillation, calcification and tattering of cartilage.

Nichols and Richardson regard the cartilage changes as the primary and characteristic feature of the disease. They observed rarefaction deep in the bone, and noted cyst formation for which they were unable to account, except possibly that it resulted from the atrophy of disuse.

Ziegler [4] calls attention to the bone rarefaction and cysts, and regards them as most significant. Wolkoff [5] thought the cysts were the direct result of trauma.

Under the microscope, the changes in the cartilage are most prominent (Fig. 3). Its cells are swollen and in groups. It presents a

4. Ziegler, Ernst: Lehrbuch der allgemeinen Pathologie und der pathologischen Anatomie, Jena, Gustav Fischer **2**: 1906.

5. Wolkoff: Verhandl. der deutsch. path. Gesellsch. **9**:229, 1905. Kimura: Beitr. z. path. Anat. u. z. allg. Path. **27**:223, 1900.

tattered, irregular and often bizarre appearance (Figs. 4 and 5). Later it disappears and leaves the thickened subjacent buttress of bone bare, though islands of it may remain. The bony thickening is suggestive of Nature's attempt to wall off the marrow from the joint (Fig. 6). The thickened synovial membrane consists largely of fat and loose meshed fibrous tissue. The villi do not possess the lymphoid appearance common to the members of the first group.

Areas of cellular infiltration are frequent in the synovial membrane (Fig. 7).

The marrow is often fatty and fibrous, as one would expect in elderly people. It contains minute spicules of bone and cartilage,

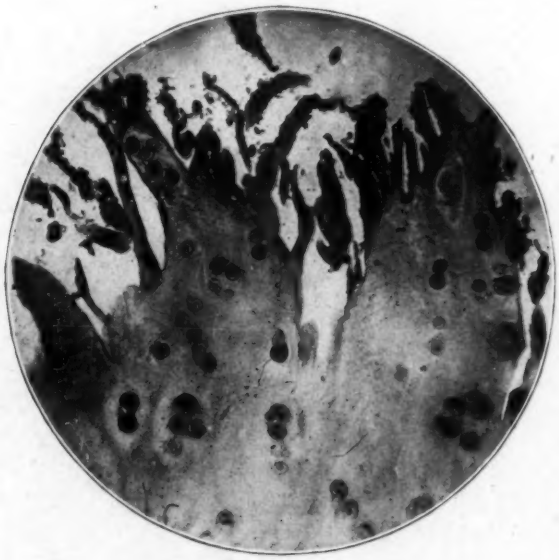

Fig. 4.—High power photomicrograph of a portion of stained section shown in Figure 3.

and the bone trabeculae close to the joint are increased in number and thickness. Areas of cellular infiltration, sometimes composed largely of plasma cells, are a prominent feature (Fig. 8). Rarefaction of the bone begins a short distance from the joint line, and is a constant and prominent feature. This rarefaction is plainly evident in the roentgenogram.

Distinct, irregular cavities were present in five of my specimens. The fifth, the head of a femur, was little else than an aseptic sequestrum. These cavities may present the typical appearance of cysts, they may be filled with fibrous tissue, or they may contain dead bone and other necrotic material. Their presence could not be detected by the

roentgen ray. In one case, however, that did not come to operation, a typical cavity, with a sequestrum, could be seen in the lower end of the femur.

Four years ago, I called attention to the cavities, seen by the naked eye, in dry bones presenting this type of arthritis.[6]

DESCRIPTION OF SPECIMENS WITH CASE HISTORIES

SPECIMEN E 187.—*History.*—The patient, a widow aged about 55, had suffered pain in the right thigh for ten or twelve years. This recently had become much worse until at the present time she can hardly walk. The mode of onset was unknown. The patient was healthy otherwise. She had had no trouble with the throat; all her teeth had been extracted ten or twelve years before.

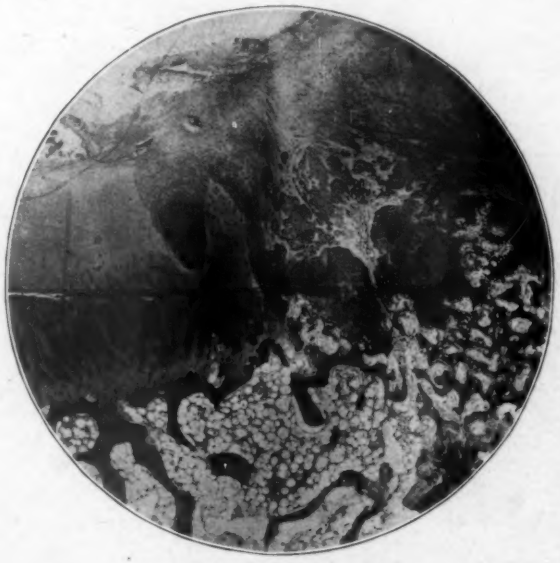

Fig. 5.—Low power photomicrograph showing irregularity in structure and outline of the joint cartilage. New bone formation going on beneath it may be noted.

She had had nine children, three were dead; one was stillborn; one died of diphtheria, and one died at 7 months. The patient limped, the right hip being in slight flexion, abduction and external rotation. The thigh muscles were atrophied. Flexion was slightly limited, other motions were markedly so. There was no Kernig nor Ely sign. The spine was rather stiff.

Treatment and Results.—Resection of the hip was performed through an anterior excision, followed by a plaster-of-Paris spica for six weeks. Thirteen

6. Ely, L. W.: A Study of One Hundred Dry Bones Sawn in the Laboratory., Bone and Joint Studies, I. Stanford University, Calif., 1916, published by the Leland Stanford Junior University.

months after operation, the patient walked fairly well, with a marked limp, but with little pain. The hip was in slight flexion and possessed a range of motion of 40 degrees (estimated). Abduction was slightly limited. The limb was 3 cm. shorter than the other.

Examination of Specimen.—The specimen consisted of the head of the femur and fragments from the acetabular rim. The joint surface of the femur jutted out over the neck inferiorly, so as to give the impression of an impaction of the neck into the head. In its central portion the head was partly eburnated, and partly covered with soft granulation tissue. Its circumferential portion was covered by cartilage, which was more or less roughened and fibrillated. In the acetabular fragment were two small cavities just beneath the cartilage.

Section of the acetabular fragments revealed the usual changes of the second type of arthritis. Section of the head in line with the neck revealed two or three cavities close to the joint line. The bone cut hard.

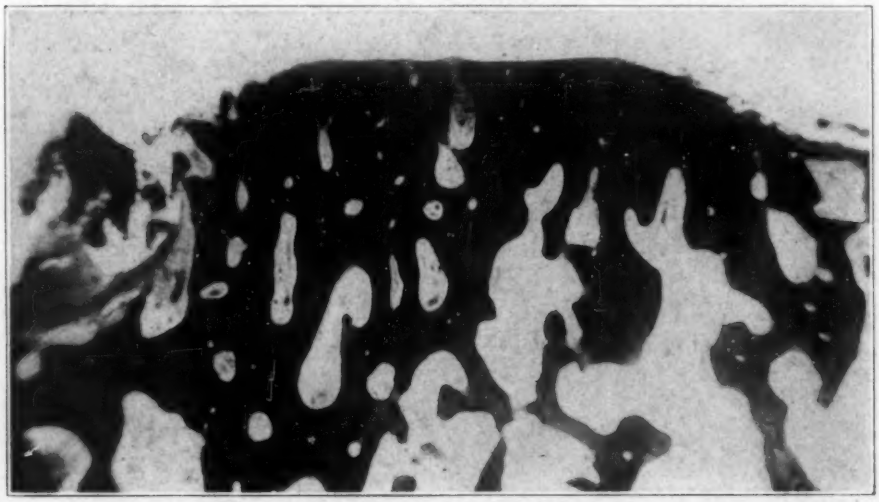

Fig. 6.—The eburnated bone at the joint surfaces, low power photomicrograph.

Histology.—Head (Figs. 9 and 10): At and near the surface was an irregular layer of dense bone about 5 mm. thick, which thinned out rapidly, so that at the depth of about 1.5 cm. the bone was more spongy than normal (Fig. 9, D and R). The cartilage was gone, except at the side, where it was thick, more or less split up, fibrous (fibrocartilage), and, on its surface, tattered. Its cells were swollen and rather transparent, and some of them had lost their nuclei. Here and there, islands of cartilage were seen on the joint surface, not lying on the bare bone, but rather in it.

The outstanding feature was the presence of cavities of greater and smaller size in the dense bone near the articular surface. Some of these were filled with fibrous tissue, rather dense, some contained necrotic tissue and dead bone, about which was a fibrous capsule. Here and there, masses of fibrous tissue intersected the dense bone at the articular surface. When they did, the adjacent bone had the bitten out appearance characteristic of rarefying osteitis, and yet new bone apparently was being developed, in this situation in

most instances directly from fibrous tissue, but here and there from cartilage. *Part of the dense bone at the surface was dead.* This could be determined not only by its empty lacunae, but also by its different reaction to stains.

The marrow near the joint consisted of little else than dense fibrous tissue. Deeper in, the marrow was fatty, and still deeper, some lymphoid marrow appeared. It was well supplied with blood vessels. No organisms were found in sections stained with Giemsa and Gram-Weigert stains.

Fig. 7.—Low power photomicrograph of joint capsule, showing the thickening of the synovial membrane and its cellular infiltration at *X*.

SPECIMEN E 168.—*History.*—A man, aged 42, who had been operated on for fistula in ano nine years before (a histologic examination of the tissue is said to have revealed tuberculosis), whose spine and wrist had been treated eight years before for tuberculosis, with plaster jackets and passive hyperemia, recently had had trouble in the knee, and the joint had been injected with liquor formaldehydi and glycerin.

Operation.—Resection of the knee was performed at the San Francisco Hospital. The specimen included the patella, the upper end of the tibia and the

lower end of the femur, with soft parts. The bacteriologic examination made at the San Francisco Hospital is said to have revealed acid fast organisms identified as tubercle bacilli.

The synovial membrane was injected, hypertrophied, succulent and villous. The bone ends were badly damaged, and showed lesions of Type II. The patella was badly scarred on its posterior aspect, which consists largely of fibrous tissue, and showed no bare bone. A tuft of villous synovial membrane covered its distal portion.

Both femoral condyles showed border exostoses, and eburnated areas. The lateral condyle had a defect on its surface, about 1 cm. in diameter, and its anterior portion was crossed by an oblique groove, anterior to which was a

Fig. 8.—Low power photomicrograph, showing cellular infiltration in the marrow.

ridge of cartilage and bone. There was a deep, eroded groove still more anteriorly on the medial condyle. The anterior surface of the lower end of the femur was irregular, and badly eroded.

The articular surface of both tibial tuberosities was eburnated in places. Border exostoses were not so prominent as in the femur. The medial tuberosity showed one large defect, the lateral, two smaller ones. A band of adhesions ran across the lateral tuberosity, between the soft parts on either side.

A section was made of the end of the tibia. A number of cavities were found close to the articular surface (Fig. 11).

Histology.—Over one side of the slide the joint cartilage showed the typical changes of the second type. It was split up, irregular and tattered. Many of its cells were absent, much of it was dead.

The cartilage of the other side was gone, and had been replaced by connective tissue, which in places had all the appearances of synovial membrane. Under this was a fairly well defined layer of rather dense trabeculae, irregular on the surface and unlike the dense, eburnated, fairly smooth bone which is usually seen. Beneath this, the bone and marrow appeared fairly normal. The latter was fatty and contained some lymphoid tissue, but was well supplied with blood vessels.

Beneath the other part of the joint, where the cartilage remained, there appeared the characteristic cavities, three or four in number, fairly distinct from one another, well walled off by bone on their joint side, and fairly well walled off on their other sides. These were filled with fibrous tissue, the greater part of which was quite dense. In the center of one was some hyalin, which was surrounded by concentric layers of fibrous tissue. In this limited area there were no blood vessels. The blood vessels were abundant in other parts of the marrow.

Rarefying osteitis was present to a limited extent, but no dead bone could be seen anywhere.

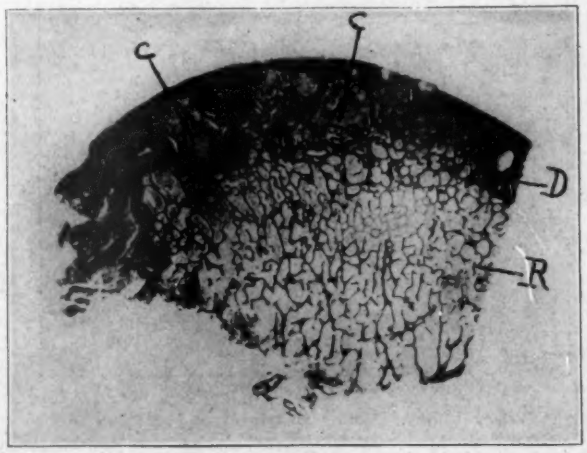

Fig. 9.—Low power photomicrograph of stained slide from Specimen E 187: dense bone at and near the articular surface, with cavity formation (*C C*) may be noted.

There was no evidence of tuberculosis. The slides on which the diagnosis of tuberculosis was based were secured, and no tubercle bacilli were found.

Sections stained with Giemsa and Gram-Weigert stains were negative for organisms.

Specimen E 225.—*History.*—A rancher, aged 64, who had complained of pain in his right hip for twelve or fourteen years, the onset of which had been slow, no history of injury could be obtained, had pain in the right knee also. After much trouble with his teeth, the patient had had them all extracted fourteen years before.

Examination.—The patient was a large, heavy-set, broad-backed man of the so-called "herbivorous" type, who walked with a moderate limp. The right lower extremity was apparently short, and was in a position of slight flexion,

and marked external rotation. All motions in the hip were decidedly limited. When flexion was forced the thigh went into abduction—fairly characteristic of this form of arthritis.

There was no actual shortening, although there was an apparent shortening of 1½ inches. The roentgenogram revealed the typical changes of an arthritis of the second type, with marked rarefaction of the head and neck (Fig. 12).

Operation.—Feb. 2, 1920, I performed resection of the hip, using the Smith-Peterson incision. The head of the femur was sent to the bacteriologic laboratory. The wound was sutured without drainage. A plaster-of-Paris spica was applied for two months, then crutches and physical therapy were used.

Examination of Specimen.—This consisted of the head of the femur and fragments of the acetabulum. In the proximal posterior part of the head, rather close to the joint surface, was a cavity about 2.5 by 1.5 by 1 cm. in diameter, filled with a gelatinous material (Fig. 13 *C*). It was situated about 2 or 3 cm. from the attachment of the ligamentum teres. It had rather dense walls.

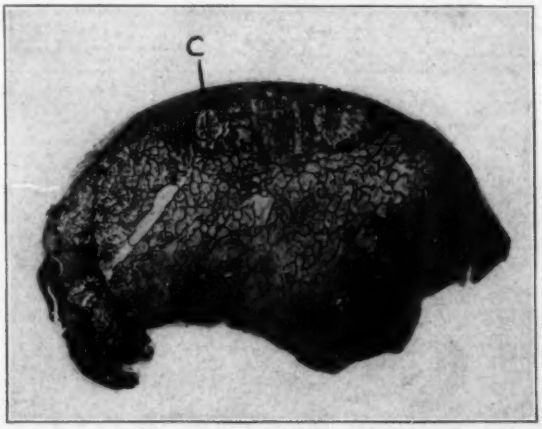

Fig. 10.—Low power photomicrograph of stained slide, from a section taken at a distance of 5 or 10 mm. from the section shown in Figure 9.

The joint surface showed the usual changes of the second type of arthritis, with eburnation. A band of soft, pink granulations, about 1 cm. wide, passed across it.

A section of the head through the cavity revealed a number of other cavities filled with gelatinous material. The stained slide (Fig. 14) presented to the naked eye a marked irregularity of structure of bone and cartilage. The articular surface was divided into two portions. On one portion the cartilage was fairly thick, and was calcified in its deeper layers. At its extremity, it contained bone in its interior (Fig 14, *B*). The cartilage was absent from the surface of the other portion.

Several large, irregular cavities (Fig. 14 *A, E, F*) besides the one on the margin of the specimen which was scooped out for culture (Fig. 14 *C*), were found in the bone near the articular surface. These were crossed by strands of fibrous tissue. As a rule the bone was fairly dense near the joint.

Histology.—The articular cartilage, present on one side of the articulation, was degenerated, fibrillated, irregular in outline, and stained deeply with

hematoxylin in its deeper portion. Calcified, necrotic masses could be seen in its interior. At its periphery a layer of new bone was being formed in its interior. This evidently formed the characteristic border exostosis or lipping.

On the other side of the articulation, a rather thin layer of dense, eburnated bone was found. This, broken up by occasional patches of fibrous tissue and cartilage, continued entirely across to the other side of the section.

When a number of slides were studied, one saw several cavities. These differed in number, shape and size, as well as in contents in the different sections. One slide near the joint surface showed little else than a succession of these cavities for about two thirds of its extent. Another would show only two or three. Some of these cavities were typical cysts or collections of cysts, others contained nothing but fibrous tissue.

Fig. 11.—Low power photomicrograph of stained slide from Specimen E 168. The arrows point to two cavities in the bone.

The large multilocular (Fig. 14 *A*) cyst contained a little detritus, in which were a few spicules of dead bone. The fibrous strands that crossed it contained both live and dead bone.

Near the large multilocular cyst was an elliptical cavity (Fig. 14 *E*). This had a well defined capsule of fibrous tissue and a fairly well defined bony wall. It lay under the rift mentioned before. This rift was filled with fibrocartilage. At the side of this elliptical cavity was seen an irregular mass of fibrous tissue (Fig. 14 *F*). In other slides, this was much larger, was well walled off by dense bone, and was quite vascular. It replaced the elliptical cavity. In other words, part of this large irregular cavity, cut across at different levels, was filled with fibrous tissue, another part was cystic.

The marrow was as a rule fibrous near the joint, and the trabeculae in this locality were evidently undergoing absorption. Deeper in, the marrow was fatty.

Cultures from the cavity, made at operation, were negative. Sections stained with Giemsa's and Gram-Weigert stain, were negative for bacteria.

SPECIMEN E 227.—*History.*—A farm hand, aged 33, who for the last twelve years had complained of pain and stiffness of both hips; the pain having begun gradually, and having grown worse, with no history of injury, who had had no sore throat, but had had much trouble with his teeth, was referred to the dental clinic, and his infected teeth and buried roots were removed.

The roentgen rays revealed marked changes of arthritis of the second type in both hips, with rarefaction in the head and neck of the femur (Figs. 15 and 16).

Fig. 12.—Hip described under Specimen E 225.

Both hips were in slight flexion and external rotation. The left was in adduction. All motions in both hips were limited, but each possessed a small range of painless motion. The left hip appeared to be involved to a greater degree than the right. Resection of this hip was advised.

Operation and Results.—March 5, 1920, resection of the left hip was performed, the Smith-Peterson incision being used. The head of the femur with part of the proximal border of the acetabulum was removed. The wound was sutured in layers. The head of the femur was taken immediately to the bacteriologic laboratory for cultures. A long plaster-of-Paris spica was applied from the axillae to the toes.

The plaster-of-Paris spica was removed on April 14, and the patient was permitted to go about on crutches.

Examination of Specimen.—The articular surface of the head presented the usual changes of arthritis of the second type, but without much eburnation. In the posterior part of the head, about 0.5 cm. from the joint line, a large irregular fusiform cavity about 1 by 1 by 2 cm. in diameter was found which was surrounded by rather dense bone, and filled with dense fibrous tissue which was removed with great difficulty (Fig. 14 *C*). It was firmly adherent to the bone.

A section of the head was made through the cavity.

The stained section of the head presented somewhat the appearance of a mushroom, the stalk of which was formed by dense bone, which had a more or less lamellar arrangement, and almost the density of cortical bone (Fig. 18).

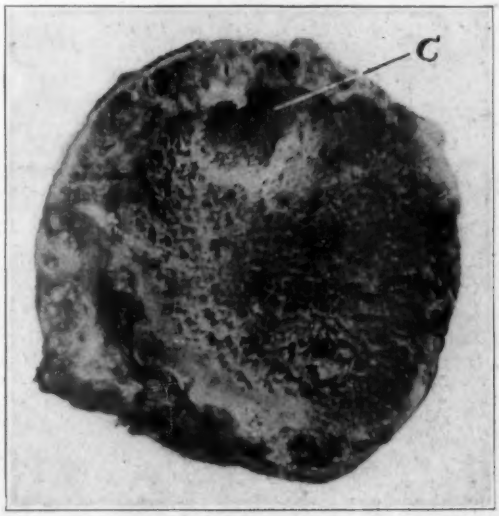

Fig. 13.—Specimen E 225 at line of section from neck of bone, showing cavity at C.

The space on one side of this (G) was an artefact, caused by gouging out the bone for cultures. (It was so soft that it was gouged out with a scalpel). On the other side was the cavity noted heretofore (Fig. 18 *C*).

The wall of the bone of the central stalk, as well as the spongy bone on the rest of the wall of the cavity, showed remnants of the fibrous tissue which was removed for bacteriologic examination, and for separate study. In this fibrous tissue were small spicules of bone, most of them dead.

The marrow throughout the specimen was almost exclusively fatty, and contained many thin-walled vessels and "blood spaces," filled with blood. This gave it the appearance of the marrow of an animal that had died of an infectious disease.

The bone trabeculae were somewhat thickened near the joint surface, but not so much as is usually the case in this type of arthritis. They presented the classic appearance of "productive osteitis," being lined by osteoblasts.

The articular cartilage was thin, irregular and degenerated, but it covered the bone completely, except for one or two small areas.

The contents of the cavity consisted of dense fibrous tissue containing necrotic material. Here and there, one could see areas of calcification, and spicules of dead bone.

Cultures from the material removed from the head were negative. No bacteria were found in the stained specimen.

The guinea-pig test was negative.

Specimen E 229.—*History.*—A laborer, aged 52, for four years had suffered pain in the left hip which he dated from an injury, a "lot of sacks" having fallen on the hip.

Examination.—The patient limped badly. The left hip was in slight flexion and adduction. Extension, rotation and abduction were limited; flexion was

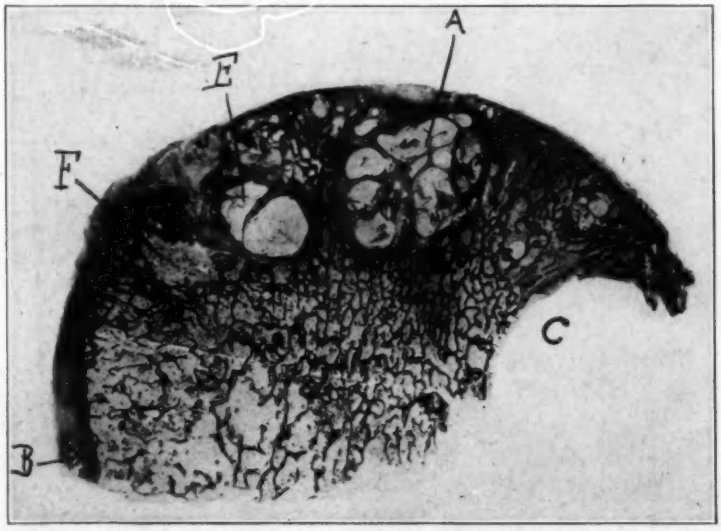

Fig. 14.—Low power photomicrograph of stained slide from Specimen E 225: C, cavity shown at operation.

free. Ely sign was positive. The hip went into abduction when flexion was forced. There was moderate muscular atrophy.

The skiagram revealed the typical changes of the second type with much rarefaction in the head and neck (Fig. 19).

The patient also had a well-marked Dupuytren's contraction in both hands.

Operation and Results.—March 13, 1920, resection of the hip was performed with the Smith-Peterson incision. The joint contained fluid, which was aspirated and sent with the femoral head immediately to the laboratory for cultures. The wound was sutured in layers with catgut. A plaster-of-Paris spica was applied from the nipples to the toes.

April 3, the plaster was removed from the foot. The patient commenced to walk with crutches. April 8, the plaster was removed from the leg. April 21, it was entirely removed. April 23, the patient left the hospital, walking with a cane.

Examination of Specimen.—The joint cartilage had a deep wrinkle, like that on an old man's skin, running across it, and in the neighborhood of this wrinkle it was detached from the bone. It appeared as if it could be rubbed off. Lipping was present at the circumference of the joint. There was no evidence of cavities in the bone.

The head was sawed in sections about 5 mm. thick (Fig. 20). It presented a most remarkable appearance. It looked as if it had been fractured near the joint, though the solution of continuity was not complete, and the fragment was still partly attached. Softened areas, dense bone and spongy bone all were seen.

Fig. 15.—Left hip described under Specimen E 227.

Histology.—A section when stained (Fig. 20 *A* and Fig. 21) revealed areas of necrosis, and patches of calcification. Much of the bone was dead, but some was alive, and where there was live bone the marrow consisted of fibrous tissue. Elsewhere the marrow as well as the bone was dead. The head, in other words, was practically a large sequestrum.

The fractured piece was dead (Fig. 21 S) and the irregular line of fracture was bounded on both sides by dead bone.

The cartilage was thick, irregular, degenerated and showed marked calcification. At one side, it was overlaid by a new formation of bone and cartilage—the typical lipping (Fig. 21 *L*).

Cultures from the head and from the joint fluid were negative. Examination of the stained specimen revealed no bacteria. The guinea-pig test was negative.

COMMENT

These five specimens present two features in addition to the typical bone production at and near the joint line and the cartilaginous changes usually described: (1) rarefaction of the bone beginning a short distance from the joint; and (2) softened areas with necrosis of a greater or less degree, with the exception of one specimen which showed no necrosis, but fibrous tissue filling the cavity.

Fig. 16.—Right hip described under Specimen E 227.

Dr. William Ophüls, who examined the sections without reading the histories, interprets them as forming a chronologic series. The fractured and necrotic head of the femur represents the most recent changes and the head of the femur containing the cysts (Specimen E 225) represents the latest stages of the pathologic process. This conclusion is sustained by the clinical histories.

We find, then, that the essential feature of this type of arthritis is an aseptic necrosis with cavity formation in the bone at a short distance from the joint.

The agent producing this necrosis is not known. No direct evidence of infection has been found.

We must discard the theory that the changes in the articular cartilage are primary. This theory is not supported by anything that we know of regarding the relation of the cartilage to subjacent bone and marrow. On the contrary, we know that any disease in the marrow just beneath the cartilage affects its nutrition, and we conclude that in this form of arthritis, as in every other, the cartilaginous changes are secondary to those in the bone and marrow.

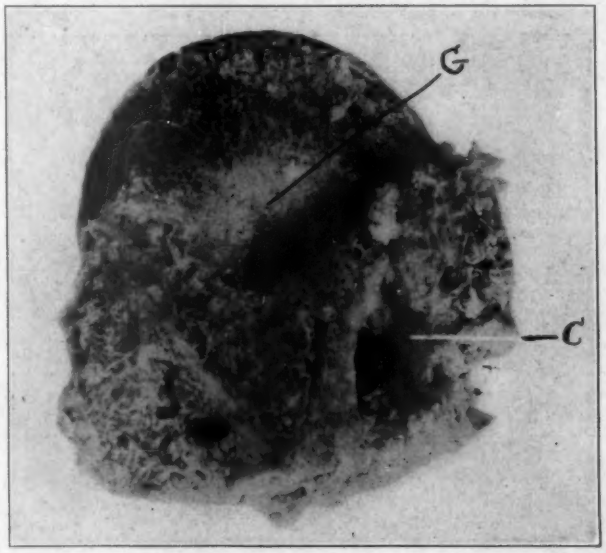

Fig. 17.—Specimen E 227 at line of section from neck, showing cavity at C. The cavity at G is an artefact caused by a portion being gouged out for culture.

Much the same may be said of the bone production at the joint line. While it is the distinguishing feature of the disease, the feature which enables us to make the diagnosis, it is not the essential feature. It is secondary to the rarefaction and is less in extent. There is nothing peculiar in this; for example, compare the dense bone about an old suppurative focus in the bone, or even the bone formed about an old tuberculous focus.

It is difficult to explain the synovitis except on the basis of trauma. This is the most plausible explanation. The joint is mechanically damaged, and a force that would not injure a normal joint may sprain a deformed one, that is, may injure its capsule.

In the past, almost every form of arthritis has been ascribed to trauma, but as our knowledge has increased we have found that trauma simply lights up an old preexisting, perhaps quiescent, inflammation. This is almost certainly the case with tuberculosis.

We must bear in mind that the bone is susceptible to only one form of mechanical injury, and that is fracture. Nothing else can affect it but disease, and this is true also of the marrow. Bone cannot be strained, sprained, torn or bruised. A mechanical force fractures it or leaves it uninjured.

Most writers believe that trauma has a distinct etiologic relationship to this form of arthritis. More often there is a repeated injury or strain associated with a laborious occupation, than one severe injury. Axhausen [7] maintained that he had produced the essential changes of

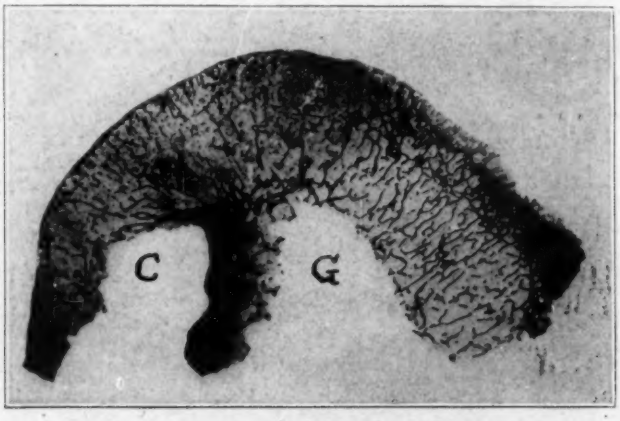

Fig. 18. — Photomicrograph of stained slide from Specimen E 227: C, cavity; G, artefact.

the disease by injuring the joint cartilage with an electric needle. It should be remembered that his electric needle would cause a necrosis of the subjacent bone and marrow. In several carefully conducted sets of experiments, John Francis Cowan and I were unable to verify his conclusions.[8] We gouged out, in our experiments, the bone and marrow and cartilage with a sharp curet.

This disease is essentially one of advanced age. It rarely occurs under 30, and is most frequently observed after 40 years of age.

Many patients have disturbed digestion. Mental emotion has been considered by some as a causative factor.

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7. Axhausen: Archiv f. klin. Chir. **99**:519, 1912.

8. Ely, L. W., and Cowan, J. F.: Reaction of the Tissues of the Knee Joint of the Rabbit to Injury. Bone and Joint Studies, I, Stanford University, Calif., published by Leland Stanford Junior University, 1911.

Regarding infection, no conclusive evidence is at hand, for no bacteria have been demonstrated in the fluid removed from the joints or the contents of the cysts. Our attempts at Stanford to isolate bacteria have been uniformly unsuccessful. No bacteria have been demonstrated in the marrow. It is important to make a sharp distinction between cases of this type and those of Type I. In the latter, positive bacteriologic results are often obtained.

Fig. 19.—Hip described under Specimen E 229.

SYMPTOMATOLOGY

I shall not go at length into this. The pain, stiffness, deformity, disability, muscular atrophy of a low grade form of chronic arthritis are present. The joint is usually swollen. This is due to fluid, thickening of the synovial membrane or new bone. In the hands, the disease attacks by preference the terminal interphalangeal joints—Heberden's nodes. It is frequent in the hip, spine and knee, and is often considered to be uniarticular except in the spine and fingers, but this uniarticular character is probably only apparent. Symptoms may be present in cnly one joint, when many ioints are affected

When the spine is affected, the pain may be felt in the back, around the trunk, or down the extremities; hence many complain of neuritis, lumbago and sciatica. Probably all cases of lumbago and "fibrositis" are really spinal arthritis, as well as many cases of sciatica and neuritis. We do not admit the existence of such a thing as lumbago or fleeting fibrositis in the orthopedic clinic. It is as illogical to ascribe the stiffness and pain in the back muscles, the pain in the back

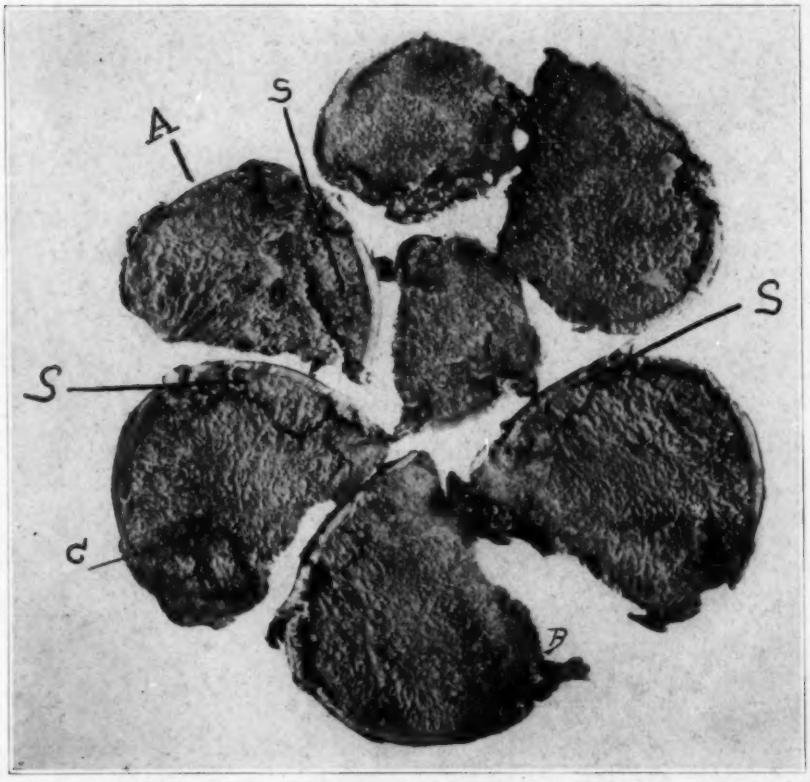

Fig. 29.—Sections of Specimen E 229. Section A was chosen for histologic examination; S, sequestrum.

and down the thighs to a myositis, "myalgia" or neuritis when the roentgen ray reveals distinct changes in the spinal joints as it would be to ascribe the pain in the hip, knee and thigh, and the muscular spasm about the hip to the same causes when the hip is diseased. The same condition is present in both cases. The use of the roentgen rays will determine the presence or absence of bony change in the spine.

TREATMENT

All sorts of curative means have been advocated—baking, massage, baths, external applications, internal medication, electricity, etc. Oil injections have been advocated on the theory that these joints were "dry." They are no drier than any other. The treatment is unsatisfactory.

The accompanying table presents a short list of our clinical patients. Many of them came only once or twice, others came often enough to enable us to work up their histories thoroughly. In some, diseased tonsils were present, in some an old deep urethritis.

The alveolar infection was determined by the roentgen ray. In some instances, there was found a definite root abscess, in others

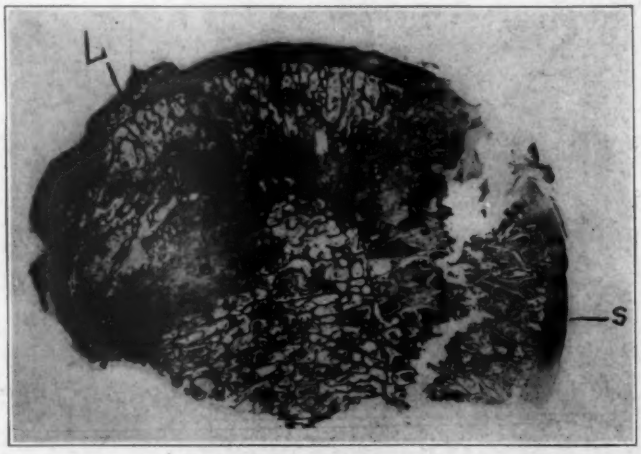

Fig. 21.—Low power photomicrograph of stained slide from Specimen E 229: S, sequestrum; L, border exostosis or lipping.

merely a rarefaction about the tooth. When patients submitted to extraction, the diagnosis could be confirmed. In some instances, no roentgenograms were taken of the teeth and a clinical diagnosis of alveolar infection was made.

ANALYSIS OF PATIENTS

Age and Sex.—An analysis of these patients shows that sixty-eight were men and twenty-two women. The age varied from 28 to 76 years. Two were in the third decade of life, twelve in the fourth, twenty-six in the fifth, thirty-two in the sixth, fifteen in the seventh and three in the eighth. Almost two-thirds of the patients were between 40 and 60 years of age.

CLINICAL PATIENTS

Case	Age	Sex*	Occupation	Condition	Infection
1	49	♂	Chauffeur	Arthritis, chronic, of knee	Alveolar
2	45	♂	Laborer	Arthritis, chronic, of spine	Alveolar
3	50	♂	Motorman	Arthritis, chronic, of knee	Alveolar
4	50	♀	Housework	Arthritis, chronic, of knee	Alveolar
5	73	♂	Tailor	Arthritis, chronic, multiple	Alevolar
6	53	♂	Laborer	Arthritis, chronic, of hip	Alveolar
7	33	♂	Farm hand	Arthritis, chronic, of hips	Alveolar
8	50	♀	Domestic	Arthritis, chronic, of spine	Alveolar
9	28	♂	Waiter	Arthritis, chronic, of spine	Alevolar
10	53	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
11	47	♂	Laborer	Arthritis, chronic, of spine	Alveolar
12	44	♂	Solicitor	Arthritis, chronic, of spine	Alveolar
13	57	♂	Bottler	Arthritis, chronic, of hip	Alveolar
14	40	♂	Laborer	Arthritis, chronic, of spine	All teeth out
15	67	♂	Entertainer	Arthritis, chronic, of spine	Alveolar
16	37	♂	Laborer	Arthritis, chronic, of spine	Alveolar
17	35	♀	Housewife	Arthritis, chronic, of spine	Alveolar
18	53	♂	Laborer	Arthritis, chronic, of hip	Alveolar
19	58	♀	Housewife	Arthritis, chronic, multiple	Alveolar
20	51	♀	Housewife	Arthritis, chronic, multiple	Alveolar
21	50	♂	Fisherman	Arthritis, chronic, of spine	Alveolar
22	50	♂	Rancher	Arthritis, chronic, of spine	Alveolar
23	57	♂	Laborer	Arthritis, chronic, of spine	Alveolar
24	63	♂	Carpenter	Arthritis, chronic, of knee	Teeth removed 10 yrs. before, 5 yrs. before pain began
25	70	♂	Farm helper	Arthritis, chronic, of spine	Alveolar
26	65	♂	Cook	Arthritis, chronic, of knee	Alveolar
27	54	♂	Milker	Arthritis, chronic, of spine	Alveolar
28	61	♂	Laborer	Arthritis, chronic, of spine	Alveolar
29	60	♀	Housewife	Arthritis, chronic, of spine	Alveolar
30	50	♀	Housewife	Arthritis, chronic, of spine	Alveolar
31	54	♀	Housewife	Arthritis, chronic, of hip	Teeth not mentioned
32	52	♀	Housewife	Arthritis, chronic, of hip	Upper teeth all gone, condition of others not mentioned
33	60	♂	Cook	Arthritis, chronic, of spine	Alveolar
34	53	♂	Laborer	Arthritis, chronic, of knee	Alveolar
35	59	♂	Solicitor	Arthritis, chronic, of spine	Alveolar
36	61	♂	Fruit picker	Arthritis, chronic, of hip	Teeth not mentioned
37	43	♂	Laborer	Arthritis, chronic, of spine	Alveolar
38	40	♀	Milliner	Arthritis, chronic, of knee	Alveolar
39	43	♀	Housewife	Arthritis, chronic, of spine	Alveolar
40	45	♂	Laborer	Arthritis, chronic, of knee	Alveolar
41	54	♂	Hod carrier	Arthritis, chronic, of spine	Alveolar
42	47	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
43	49	♀	.....	Arthritis, chronic, of spine	Alveolar
44	48	♂	Laborer	Arthritis, chronic, of knee	Alveolar
45	43	♂	Furniture work	Arthritis, chronic, of knee	Teeth poorly kept
46	76	♀	Domestic	Arthritis, chronic, multiple	Alveolar
47	48	♂	Marble polisher	Arthritis, chronic, of shoulder	Alveolar
48	35	♂	Moving picture operator	Arthritis, chronic, of spine	All teeth pulled 3 mos. before examination
49	41	♂	Switchman	Arthritis, chronic, of spine	Alveolar
50	41	♂	Miner	Arthritis, chronic, of hip	Alveolar
51	37	♂	Laborer	Arthritis, chronic, of spine	Teeth negative
52	64	♂	Laborer	Arthritis, chronic, multiple	Alveolar
53	57	♀	Housework	Arthritis, chronic, of knee	Alveolar
54	48	♂	Laborer	Arthritis, chronic, of spine	Alveolar
55	50	♀	Housewife	Arthritis, chronic, of knee	No note on teeth
56	60	♂	Miner	Arthritis, chronic, of spine	All teeth out
57	50	♂	Laborer	Arthritis, chronic, of spine	Alveolar
58	39	♂	Laborer	Arthritis, chronic, of knee	Alveolar
59	34	♀	Housewife	Arthritis, chronic, of knee	Teeth negative
60	52	♂	Laborer	Arthritis, chronic, of spine	Teeth negative
61	48	♂	Laborer	Arthritis, chronic, of knee	Alveolar
62	44	♀	Housewife	Arthritis, chronic, of ankle	Alveolar
63	49	♂	Iron worker	Arthritis, chronic, of spine	Alveolar
64	55	♂	Dishwasher	Arthritis, chronic, of spine	No note of teeth
65	51	♂	Farmer	Arthritis, chronic, of spine	Teeth not mentioned
66	43	♂	Laborer	Arthritis, chronic, of spine	Alveolar
67	61	♂	Collector	Arthritis, chronic, of hip	Alveolar
68	45	♂	Laborer	Arthritis, chronic, of spine	No note on teeth
69	32	♂	Peddler	Arthritis, chronic, of spine	Alveolar
70	56	♀	Seamstress	Arthritis, chronic, of knee	Alveolar
71	39	♂	Iron worker	Arthritis, chronic, of knee	Alveolar
72	56	♂	Engineer	Arthritis, chronic, of spine	Alveolar
73	34	♂	Laborer	Arthritis, chronic, of spine	Alveolar
74	45	♂	Cook	Arthritis, chronic, of knee	Teeth negative

* In this column, ♂ represents male and ♀, female.

CLINICAL PATIENTS—(*Continued*)

Case	Age	Sex	Occupation	Condition	Infection
75	57	♀	Housework	Arthritis, chronic, multiple	"Teeth false"
76	67	♀	Housework	Arthritis, chronic, of knee	"All teeth gone"
77	39	♂	Marine fireman	Arthritis, chronic, of spine	Alveolar
78	40	♂	Metal worker	Arthritis, chronic, of spine	Alveolar
79	62	♂	Laborer	Arthritis, chronic, of knee	Alveolar
80	40	♂	Laborer	Arthritis, chronic, of spine	Alveolar
81	48	♂	Waiter	Arthritis, chronic, of knee	Alveolar
82	62	♀	Housewife	Arthritis, chronic, of spine	Teeth not mentioned
83	59	♂	Laborer	Arthritis, chronic, of hip	Alveolar
84	69	♂	Cook	Arthritis, chronic, of shoulder	Alveolar
85	60	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
86	58	♂	Printer	Arthritis, chronic, of hips	Alveolar
87	38	♂	Laborer	Arthritis, chronic, of spine	Alveolar
88	59	♀	Housewife	Arthritis, chronic, of knee	Alveolar
89	55	♂	Hotel worker	Arthritis, chronic, of spine	Alveolar
90	26	♂	Miner	Arthritis, chronic, of knees	Alveolar

Occupation.—Nothing suggestive appears in this connection. The occupations are those of the ordinary clinical patients. The occupations of most necessitated hard physical work, but so do those of most clinical patients. This, of course, does not apply to my private patients.

The outstanding fact in the histories is the prevalence of alveolar infection. In seven of the histories the condition of the teeth is not mentioned. In one case, it is stated that "the upper teeth are all gone." The condition of the remainder is not mentioned. In one the history reads "teeth poorly kept." Of the remaining eighty-one, the teeth were negative in four. Even these cases reported negative, in the light of recent experience, must be regarded with suspicion. Case 90 was reported negative, but he had infected tonsils which were removed. On our insistence a second set of roentgenograms was taken, abscesses were discovered, and the correctness of the later diagnosis was esablished by extraction. Seven patients had lost all their teeth, presumably because of alveolar infection. Seventy patients had alveolar infection. In other words, depending on how one regards the cases in which the teeth had already been extracted, seventy-seven out of eighty-one, or seventy out of seventy-four, patients had alveolar infection. Deduction: The vast majority of patients with this type of arthritis have alveolar infection.

Treatment.—The bone and cartilage changes, the actual deformities of the joints, are permanent. No treatment except operation will correct them. If they are slight, operation is hardly justifiable; if more extensive, the underlying bone changes are probably so great as to render the results of operation useless or unsatisfactory.

Clinically, we recognize that alveolar infection is the fundamental cause. Therefore, if there is any evidence of infection, the teeth or roots should be extracted. This is the first step in the treatment.

If the pathologic changes are not too great, some improvement will be seen following this. Possibly, if the joints are protected from trauma, they will functionate in a manner approaching normal. Usually, there will be a slight limitation of motion. A light brace may be used to prevent strain. This is rarely necessary.

If the pain continues and is not very severe, dry heat—baking—usually makes the patients fairly comfortable. Other physical therapeutic agents, baths, electricity, etc., do the same. Gentle massage may be given, but forced motion is absolutely contraindicated. It merely damages the joint.

Immobilization is of doubtful efficiency. Passive hyperemia—Bier treatment—often lessens pain.

In severe cases of arthritis of the hip and knee, very rarely in spinal arthritis accompanied by great pain, operation affords the only hope of relief. In the knee, the operation should consist of a resection with the idea of producing a bony ankylosis. When ankylosis occurs the pain subsides.

In the case of the hip, the head of the femur should be removed. Then the trochanter may be thrust into the acetabulum, or the femur may be allowed to dislocate. In either case, the limb should be immobilized in abduction for two or three months. As an alternative for resection, the Albee ankylosing operation may be performed.

In the resection, the ordinary anterior incision is most unsatisfactory, and the removal of the head through it is very difficult. My experience with the Smith-Peterson incision has caused me to be most enthusiastic over it; my intention at present is to employ no other, except occasionally to meet some special indication. If a small part of the proximal border of the acetabulum is chiseled off, the head can be dislocated by an assistant, and sawed or chiseled off very easily.

When a limited section of the spine is involved, an ankylosing operation occasionally may be indicated, but often the spinal joints are ankylosed by Nature, through the means of new bone which forms over the anterior surface of the bodies of the vertebra. Bony ankylosis in the spine proves the one exception to our rule that bony ankylosis is never associated with this type of arthritis.

CONCLUSION

1. The great second type of arthritis has two distinguishing clinical features: (*a*) bone production (lipping, spurring) at the joint line, and (*b*) absence (except in spinal involvement) of union between the ends of the bones, either fibrous or bony.

2. Its main pathologic feature is the presence of areas of aseptic necrosis in the bone near the articular surface. This is the primary change. The cartilage changes and the bone production are the result of it.

3. Its primary cause is probably infection in the alveolar processes of the jaws.

4. Infection in the jaws causes only this type of arthritis,[9] never the first type.

5. The infections which cause the first type, namely, tuberculosis, syphilis, tonsillar and deep urethral infections, never cause this second type. The evidence for 3, 4 and 5 is purely circumstantial. It rests on clinical observation exclusively.

6. Mental emotion and disturbed digestion can only be considered as contributing causes, which change the secretions of the mouth, and make the infection in the jaws more active.

7. Trauma is effective only as straining a joint already mechanically damaged.

8. This is called the senile type of arthritis, merely because elderly people are prone to it. Alveolar infections are more common in the aged. It occurs occasionally in young people whose teeth and jaws are infected.

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9. That is, Goldthwait's atrophic arthritis, Nichols and Richardson's proliferative arthritis, the English rheumatoid arthritis, etc., which result in fibrous and bony ankylosis.

A COMPARATIVE STUDY OF SODIUM IODID AS AN OPAQUE MEDIUM IN PYELOGRAPHY *

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The purpose of this article is to give the results of a comparative experimental study of the properties of the substances commonly used in pyelography, together with the clinical results obtained with sodium iodid. The use of this substance in roentgenography was first suggested by myself [1] in 1918. A further study confirms certain observations and conclusions made at that time and also makes necessary certain modifications, which will be noted later.

In 1906, Voelcker and Lichtenberg [2] reported the use of collargol in pyelography, and until recent years colloidal silver preparations have been used almost exclusively for this purpose. It was natural at first to consider colloidal solutions as exceptionally adapted for pyelography. For by such means, heavy elements which are relatively opaque to the roentgen ray could be introduced into the kidney pelvis in a comparatively innocuous state. An increasing experience, however, has shown that colloidal silver solutions when used in pyelography may cause necrosis of kidney tissue and produce other harmful effects. This has been commented on by a number of men, and, in fact, the men who first recommended the solution reported that in one patient operated on twenty-four hours after pyelography, some of the silver preparation was seen about the kidney pelvis and ureter. More recently, Braasch and Mann,[3] and Burns and Hopkins [4] have reported further investigations, emphasizing the danger in the use of colloidal silver preparations.

Possibly in this connection the well-known effect of electrolytes on colloidal solutions has not been sufficiently emphasized. It should be understood that many colloidal solutions of silver, at least, are very unstable in the presence of urine which always contains electrolytes in

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1. Cameron, D. F.: Aqueous Solutions of Potassium and Sodium Iodids as Opaque Mediums in Roentgenography, J. A. M. A. **70**:754 (March 16) 1918. Cameron, D. F., and Grandy, C. C.: Sodium and Potassium Iodids in Roentgenography, ibid. **70**:1516 (May 25) 1918.

2. Voelcker and Lichtenberg: Pyelographie (Roentgenographie des Nierenbeckens nach Kollargolfüllung), München. med. Wchnschr. **53**:105, 1906.

3. Braasch, W. F., and Mann, F. C.: Effects of Retention in the Kidney of Media Employed in Pyelography, Am. J. M. Sc. **152**:336 (Sept.) 1916.

4. Burns and Hopkins: A Comparative Study of the Effects of Thorium and Other Substances on the Renal Parenchyma When Retained, J. Urology **2**:145, 1918.

appreciable concentrations. When urine is added to a colloidal silver solution in a test tube, no immediate reaction is visible; but in the course of a few minutes the solution, which at first was clear, if kept at body temperature, becomes granular in appearance, and gradually a heavy precipitate forms. This fact undoubtedly accounts for the frequent finding of, and probably constant deposit of, precipitated silver throughout the kidney parenchyma after pyelography with a colloidal silver medium.

In 1913, Kelly and Lewis [5] recommended a silver iodid emulsion as a suitable medium, and this has proved quite serviceable, though it is apparent that some suitable nonviscid solution would be preferable.

In 1915, Burns [6] introduced the neutral citrate solution of thorium nitrate for this purpose. This solution, which Sollmann and Brown [7] had found to be rather inert pharmacologically, proved to have such great advantages over the other pyelographic mediums in use that it supplanted practically all of them and today is probably used more frequently than any other. The fact that this solution has been used so many times with no apparent harmful effect, and that quite good roentgenograms have been obtained is sufficient evidence as to its usefulness. This medium differs in principle from others in that it is a solution of a crystalloid and not an emulsion or colloid. However, by virtue of this fact, it loses one of the advantages of the colloids, namely, a low osmotic pressure; for it is evident that an ideal medium should have an osmotic pressure within the limits of that of a concentrated urine as a maximum and that of blood as a minimum, and, although the opacity of the thorium solution is generally sufficient, at times a more opaque medium would be preferable. Another disadvantage, though not serious, is the fact that thorium nitrate is not always easily obtained, and the standard solution is prepared with some difficulty. Again, though the viscosity of the neutral thorium citrate solution is comparatively low, still it is considerably higher than that of simple aqueous solutions of ordinary inorganic salts. This is a definite disadvantage, for it delays somewhat the filling of the kidney pelvis and so allows a greater dilution with urine and as a result the definition of the roentgenograms is impaired. However, it must be stated that in general the thorium solution is a very satisfactory pyelographic medium, and its use is attended by practically no harmful effects.

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5. Kelly and Lewis: Silver Iodid Emulsion—A New Medium for Skiagraphy of the Urinary Tract, Surg., Gynec. & Obstet. **16**:707, 1913.

6. Burns, J. E.: Thorium, A New Agent in Pyelography, J. A. M. A. **64**:2126 (June 26) 1915.

7. Sollmann and Brown: Pharmacologic Investigations of Thorium, Am. J. Physiol. **18**:426, 1907.

In March and May, of 1918, I [1] suggested that certain solutions of the alkali iodids possessed certain advantages over other pyelographic mediums. In particular, it was noted that these substances were nontoxic when absorbed in ordinary amounts, and that their simple aqueous solutions were neutral in reaction, and did not form precipitates with urine. Their opacity to roentgen rays was good, their viscosity low, and they were less expensive than the other solutions in use. These solutions were not hit on by accident, but were selected after a systematic survey of the different compounds of the heavier common elements. Those which were known to be toxic or which formed precipitates with albumin or urine were excluded. Other things being equal, the substance that contained the heaviest elements and that would fulfil these conditions would be most suitable for the reason that its opacity to roentgen rays would be greater than that of solutions of other substances in the same concentration. Solutions of various compounds of bismuth, lead and strontium were tested. It was also attempted to take advantage of the property of citrates and similar organic bases to keep in solution and even render less toxic certain otherwise insoluble and toxic substances. But the results were not promising. Nor did there seem to be any suitable compound of a heavy element and one of the heavier halids, although at first it was thought that one was found in strontium iodid; but this proved to form a slowly appearing precipitate in urine. Nor were the different halid compounds other than those of iodin overlooked accidentally. It was evident that iodin, being by far the heaviest of these, would have the greatest opacity, and so could be used in weaker solutions which would have a comparatively low osmotic pressure. When the alkali iodid solutions were proposed, a 25 per cent. aqueous solution of either the sodium or potassium salt was suggested as best suited for pyelography. In the first article, it was stated that the potassium and sodium salts were used interchangeably. In the second, it was again stated that either could be used, but that the sodium salt was to be recommended. In a note [8] published in June, 1919, certain modifications of these recommendations were given. In particular, it was noted that weaker solutions could be used and that the sodium iodid was much more satisfactory.

In October, 1918, Weld [9] published an article on the use of sodium bromid in pyelography. In this article, reference was made to neither of my articles on the use of sodium and potassium iodids which appeared in earlier issues of the same journal. And although it was

8. Cameron, D. F.: The Use of Iodids in Pyelography, J. A. M. A. **72**:1737 (June 14) 1919.

9. Weld, E. H.: The Use of Sodium Bromid in Roentgenography, J. A. M. A. **71**:1111 (Oct. 5) 1918.

definitely stated in the second article that I recommended the use of the sodium salt, in the body of his article, Weld mentioned only the fact that I had recently suggested the use of potassium iodid, and added that its use in a number of cases was attended by serious reactions. Weld recommended a 25 per cent. solution of sodium bromid as being less toxic and much less expensive than potassium iodid and of about the same opacity in the same concentration. This statement concerning the relative opacity of these solutions will be shown later to need considerable modification. However, as experimental evidence in support of it, there was given a series of comparative roentgenograms of a number of alkali halids in different dilutions, together with one of a standard thorium solution.

In December, 1918, Burns and Swartz [10] showed that the ordinary dyes used in renal function tests, together with certain other substances, were absorbed quite rapidly from the pelvis of a kidney with an occluded ureter. They determined quantitatively the rate of excretion of these substances by the normal kidney under varying conditions of pressure and hydronephrosis.

In May, 1919, Weld [11] reported similar observations when pyelographic mediums were substituted for the dyes. In view of the rapid absorption of substances retained in the kidney pelvis, he emphasized the fact that the pyelographic mediums should be nontoxic. Little difference was found in the effect on renal parenchyma of solutions of sodium bromid and of potassium iodid in the same percentage concentrations. In accordance with the observations of Stockman and Charteris,[12] and many others, Weld found that potassium iodid in concentrated solution given intravenously was very toxic, while a concentrated solution of sodium bromid was quite nontoxic. Since the thorium solution also given intravenously in moderate amounts may at times be toxic, Weld concluded that the 25 per cent. sodium bromid solution was the safest and best medium so far recommended for pyelography.

It is possible that this conclusion is correct; but it is quite evident that the work so far reported in support of it is open to serious criticism. In the first place, this conclusion is based partly on the assumption made by Weld in his first article that bromids and iodids in the same concentrations have approximately the same opacity to the roentgen rays. This assumption will be shown later to be entirely erroneous in its application to pyelography. Again, it will be noted that in his comparative tests of toxicity, sodium iodid solutions received

10. Burns and Swartz: Absorption from the Renal Pelvis in Hydronephrosis Due to Permanent and Complete Occlusion of the Ureter, J. Urology **2**:445, 1918.

11. Weld, E. H.: Thesis, University of Minnesota, May, 1919.

12. Stockman and Charteris: Jour. Physiol. **26**:277.

no consideration. This is a serious omission for two reasons: first, because sodium iodid when used in pyelography or given intravenously is quite nontoxic in contrast to potassium salts whether bromid or iodid, and the toxicity of different pyelographic mediums given intravenously was one of the factors especially emphasized by Weld; second, we [13] stated that we recommended the sodium iodid in preference to the potassium salt, and gave it precedence in the title.

Since I first suggested the use of alkali iodids in pyelography, opportunity has been afforded to investigate more thoroughly the toxicity of different solutions and certain of their physicochemical properties which have an important bearing on their usefulness in pyelography. The results of this investigation, together with a report of my personal experience in the use of sodium iodid solutions in pyelography at the University Hospital, Minneapolis, will be given herewith.

EXPERIMENTAL

OPACITY TO ROENTGEN RAYS

A sufficient opacity to roentgen rays and harmlessness to the patient are the two evidently necessary characteristics of pyelographic mediums. In order to make comparable tests of the suitability of the different mediums, it is first necessary to determine what strength solutions have the same opacity under the conditions in which pyelograms are made. If the statement made by several investigators that the opacity of elements to roentgen rays varies directly with their atomic weights were true, the relative opacity problem would be very simple. On the basis of such a relation, it is evident that, with minor corrections, solutions of different substances would be equally opaque if prepared in such a way that the product of the concentration of the dissolved substance by its molecular weight were constant. And it would also follow, with minor corrections for volume, that the opacity of a 25 per cent. solution of sodium bromid, for example, would be the same as the opacity of a 25 per cent. solution of any other substance. For it is evident that in such solutions the concentration of the molecules of the dissolved substance is inversely proportional to its molecular weight, and that the product of these two quantities would be constant, except for minor corrections. In accord with this, Weld stated that 25 per cent. solutions of bromids and iodids had approximately the same opacity, showing certain roentgenograms as evidence.

In contrast to Weld's conclusion, it will be shown later that a 13.5 per cent. solution of sodium iodid is slightly more opaque than a 25 per cent. solution of sodium bromid when exposed to roentgen rays of the

13. Footnote 1, second reference.

same quality as used in pyelography, and with the filter correction which duplicates as nearly as possible the condition under which pyelograms are made.

The probable explanation of the differences here noted is simple. In the first place, it will be seen from an inspection of Weld's own illustrations that the observations he reported are incomplete. He states that the illustrations show little or no difference in opacity between the same concentrations of bromids or iodids. It is true they do not show a great difference, but still it is evident that the iodid shadows are the more dense. But there are still several other interesting features. It will be noted that the difference in density of the 12 per cent., 25 per cent. and 37 per cent. iodid solutions of each substance is comparatively slight. This means that the solutions were not exposed to roentgen rays of sufficient penetration to differentiate these solutions. But in the bromid shadows there is a much better differentiation, especially between the 12 per cent. and 25 per cent. solutions — which means that these solutions are relatively not so opaque. And, indeed, some of the 12 per cent. iodid shadows illustrated appear only slightly less dense than the 25 per cent. bromid ones. However, this difference may be brought out much more clearly. For accuracy, several precautions are necessary. The containers for the solutions should not be ordinary unstandardized bottles, the glass of which casts appreciable shadows, but should be thin-walled containers of standardized size made of uniform material of the least possible opacity. For this purpose, from a large shipment, four very thin-walled test tubes were selected whose diameters were greater than 18.2 mm. and less than 18.7 mm. The opacity of the tubes themselves to the roentgen rays used is very slight and practically constant, so that a minimum constant error is produced. The solutions themselves were made with accuracy from chemically pure materials and distilled water. The molecular as well as percentage concentration is given. The former is by far the more convenient when different dilutions are used. The neutral thorium solution was prepared according to the directions given by Burns. Thorium nitrate free from water of crystallization was used. It should be noted that it is not exactly correct to call it a 15 per cent. thorium nitrate solution as is customary, because 15 gm. of thorium nitrate in addition to a considerable quantity of sodium citrate and some alkali dissolved in a sufficient amount of water to make 100 c.c. does not make a 15 per cent. solution. It is better designated as a $\frac{5}{16}$ molar solution of thorium nitrate. The exposure to roentgen rays was made under conditions which duplicate as far as possible those under which pyelograms are made. A great error results if rays of low penetration are used. It is well known and easily demonstrated that quite light substances such as hair and gauze, not to mention the lighter

elements like sodium, magnesium and aluminum, for example, will cast quite dense shadows if rays of very low penetration are used, while their shadow is entirely invisible or scarcely visible when the rays used are sufficiently "hard" to penetrate in quantity the human body at the level of the kidney. From this it is evident that in comparative experimental tests of opacity not only must the penetration be as great as that used in pyelography, but also all of the soft rays must be filtered off by suitable means, since they are filtered off in passing through the body. Figure 1 illustrates the relative opacity of the different solutions under the conditions indicated, and is only one illustration chosen from a number made under similar conditions and with the same results. These solutions were also exposed to "softer" rays,

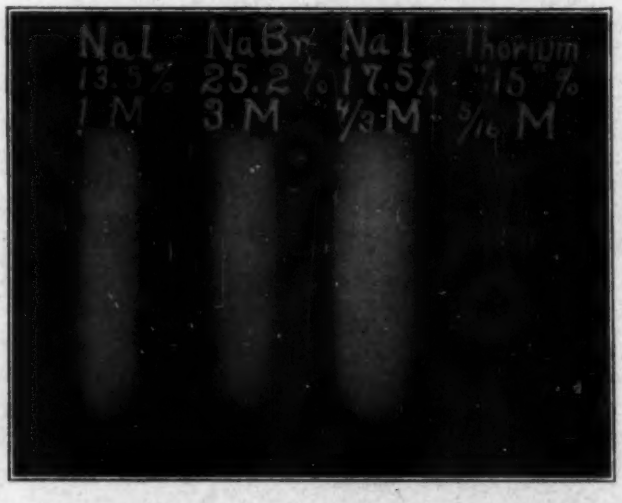

Fig. 1.—The relative opacity of the solutions indicated under the conditions noted (Coolidge tube, 20 inches distance, 4.5 inches alternate spark gap, 38 milliamperes current, 5 seconds exposure). A 4 mm. aluminum filter was placed in front of, and a similar thickness behind, the tubes, corresponding, in general, to the obstruction due to the abdominal walls encountered in practice. The time of exposure, penetration and current are the same as those used generally in pyelography. The thorium shadow on the original negative was relatively denser, and the contrast between the various shadows was less distinct, than in this illustration. Other roentgenograms made under the same conditions except with a 6 inch spark gap and 20 milliampere current showed the same result except that the iodid shadows were relatively still more intense. The roentgenograms made with 3 inches penetration and less showed denser thorium and bromid shadows.

that is, to rays from a tube with an alternate spark gap of only 3 inches. This has the effect of making the bromid and thorium shadows relatively denser, especially when none of the very soft rays are filtered off by aluminum plates.

From several series of experiments, of which only one plate is reproduced, it may be stated definitely that with conditions for pyelography duplicated, the molar (13.5 per cent.) solution of sodium iodid has the same or even a trifle greater opacity than a 3 molar (25.2 per cent.) solution of sodium bromid, and further, that these two solutions have a definitely greater opacity than the standard neutral thorium citrate solution.

Aside from its bearing on pyelography, this result in the case of iodids and bromids is of interest in that it agrees closely with the results obtained by various physicists who have investigated the opacity of elements to roentgen rays by different and more exact methods. The most convenient summary of results of experiments in this line will be found in two comparatively recent publications by Auren.[14] Certain of his results, with which my own are in accord, are of particular interest. He states that iodin with two or three other elements, not including bromin, possesses the property of selective absorption of roentgen rays especially marked with the rays of high penetration. In other words, iodin and the compounds of iodin are much more opaque to the roentgen rays than would be expected from the known properties of this element and its position in the periodic table. Auren gives the "roentgen-ray atomic absorption coefficient" of practically all of the ordinary elements, and from this table the opacity of any concentration of the commoner substances can be calculated. A few of these values of particular interest in this connection are transcribed in Table 1. The molecular absorption coefficient of water is arbitrarily taken as unity.

The values given in Table 1 represent the average opacity of the elements to comparatively soft rays. Of particular interest are the values for different wave lengths. These values, which show the selective absorption property of iodin, are given in Table 2.

The "hardness" of the rays (which varies inversely with their wave lengths) is represented by the thickness of the aluminum filter indicated above the absorption coefficient values. The penetration used in pyelography corresponds to that represented in the third and fourth columns. The values shown in Table 2 are seen to agree almost exactly with those obtained by myself as shown in Figure 1. That is, one iodin atom has the opacity of three bromin atoms to waves of this length. It should be added that the plates that I exposed to softer rays showed a relatively greater opacity of the bromid and thorium solutions, which agree closely with the values shown in column 1. When soft rays are used, the shadows of the thorium and bromid solutions are more dense than the molar iodid solution. But it is very

14. Auren, T. E.: Notes on the Absorption of X-Rays, Phil. Mag., Series 6, **33**:471; The Absorption of X-Rays, ibid. **37**:165.

important to note that such rays are much softer than those used in pyelography, and the absorption values so obtained are in no way applicable in pyelography.

Auren and most physicists in their work measure the intensity of transmitted roentgen rays by the degree of ionization produced in a protected chamber behind the absorbing medium. This method of measuring intensity is more accurate than the photographic method, but in testing pyelographic mediums the photographic method is of relatively greater value. However, from the work of Barkla and

TABLE 1.—ROENTGEN-RAY ATOMIC ABSORPTION COEFFICIENT OF VARIOUS ELEMENTS

Element	Atomic Weight	Atomic Number	Absorption Coefficient
Hydrogen	1	1	0.05
Oxygen	16	8	0.9
Sodium	23	11	1.9
Aluminum	27	13	3.4
Potassium	39	19	11.1
Calcium	40	20	14.4
Bromin	80	35	154.0
Silver	108	47	300.0
Iodin	127	53	315.0
Lead	207	82	569.0
Thorium	232	..	(1,000, approximately, by interpolation, D. F. C.)
Uranium	239	92	1,123

TABLE 2.—VALUES OF DIFFERENT WAVE LENGTHS

Element	Atomic Weight	Atomic Number	Absorption Coefficient			
			I 1.2 mm. Aluminum Filter	II 2.5 mm. Aluminum Filter	III 5 mm. Aluminum Filter	IV 10 mm. Aluminum Filter
Bromin	80	35	152.5	137.7	119.9	100.0
Iodin	126	53	326.0	352.0	356.0	366.0

Martyn [15] and others, it is known that the photographic effect of rays is rather variable. Soft rays produce relatively too great, and hard rays relatively too little effect on the photographic plate. Irregularities in the photographic film, secondary radiation induced and exposure to heterogeneous rays are also disturbing factors. Under similar conditions, however, the results obtained by the two methods are not widely divergent. And an examination of the results makes evident the fact that no simple relation exists between either the atomic weight or the atomic number of an element and its absorption coefficient. Bragg and Pierce,[16] in an investigation of this relationship, came to the con-

15. Barkla and Martyn: Photographic Effect of X-Rays, Phil. Mag., Series 6, **25**:296.

16. Bragg and Pierce: Absorption Coefficients of X-Rays, Phil. Mag., Series 6, **28**:626.

clusion that the atomic absorption coefficient of an element varied with the fourth power of the atomic number, but, as yet, there is no generally accepted formula connecting these values. It is important that these facts should be emphasized in medical literature for, through ignorance of them, a number of incorrect statements have been made in recent medical publications involving the question of the relative opacity of pyelographic mediums. It will be seen that among the lighter elements the roentgen-ray opacity increases relatively slowly with atomic weight, while with the heavy elements this increase is much more marked.

In general, for ordinary pyelographic work, the molar (13.5 per cent. solution of sodium iodid and the 3 molar [25.2 per cent.]) solution of sodium bromid have the same opacity and the opacity of the standard thorium solution is definitely less, corresponding approximately to that of a 10 per cent. sodium iodid solution. And from the data given, the important fact is obvious that with increasing roentgen-ray penetration the relative opacity of the iodid solution increases and the opacity of the bromid and thorium solutions decreases. Moreover, this difference is not slight but is very marked, and constitutes one of the real advantages of the iodid solution in pyelography.

TOXICITY

In contrast to the comparative ease and accuracy with which the opacity of these solutions can be determined, the determination of their relative toxicity is less satisfactory, especially since the toxic effects of none of them are marked. But it is evident that in order to obtain comparable results, solutions of the same opacity must be used. It is also evident that the toxicity of these solutions may be due either to the specific action of the substances in solution on different living tissues, or to the effect of the hypertonic solution in which the substances are carried, or to a combination of these two effects.

The effect of these solutions on the kidney itself is naturally the first to be determined. For this test, normal and hydronephrotic dog kidneys were used, and both functional and anatomic changes were determined when possible.

RESULTS OF EXPERIMENTS

EXPERIMENT 1.—A cannula was inserted into each ureter of a dog which was kept under ether anesthesia. One c.c. of phenolsulphonephthalein was given intravenously. Diuresis was stimulated by giving Ringer's solution and hypertonic glucose solution[17] intravenously. In twenty-five minutes, the urine excreted

17. Woodyatt, R. T.; Sansum, W. D., and Wilder, R. M.: Prolonged and Accurately Timed Intravenous Injections of Sugar, J. A. M. A. **65**:2067 (Dec. 11) 1915.

by the right kidney contained 32 per cent. of the dye, the left 35 per cent. Thereupon the right kidney pelvis was filled with a molar solution of sodium iodid which was kept under a pressure head of from 34 to 32 inches of the solution for twenty minutes. The secretory pressure of the kidney was approximately 32 inches, since the height of the fluid fell gradually from 34 inches to that level, where it remained quite constant. The blood pressure was recorded continuously throughout the experiment and was not affected materially at any time as a result of the intravenous injections or distention of the kidney pelvis. The urine collected during this time at five minute intervals from the left kidney showed no iodid when tested with chloroform, acetic acid and hydrogen peroxid.

After the expiration of twenty minutes, the pressure of the sodium iodid solution on the right kidney pelvis was discontinued and a rest of five minutes

Fig. 2.—Right pyelogram with molar (13.5 per cent.) solution of sodium iodid; capacity of pelvis, 10 c.c. Patient was an unusually heavy man.

allowed. One c.c. of standard phenolsulphonephthalein solution was again given intravenously, and the urines were collected for fifteen minutes. In this period, the right kidney excreted 26 per cent., and the left, 28 per cent.

The right kidney pelvis was then kept distended for fifteen minutes with a 3 molar (25.2 per cent.) solution of sodium bromid under a head of from 36 to 34 inches, the secretory pressure of the kidney apparently having risen somewhat for the specific gravity of the bromid solution is appreciably higher than that of the iodid. At the end of this period a functional test was again made, the right kidney excreting 27 per cent., and the left, 31 per cent., of the dye in fifteen minutes.

Experiment 2.—Experiment 1 was in part repeated on a second dog, but unfortunately the specimens of the preliminary functional test were lost. After

the right kidney pelvis had been kept distended for twenty-five minutes with a molar sodium iodid solution at secretory pressure, the functional test was repeated, the right kidney excreting 40 per cent., and the left 40 per cent. of phenolsulphonephthalein.

At the conclusion of these experiments, the kidneys were removed and examined for gross and microscopic changes, but none were noted. In these experiments no immediate diminution in renal function, as indicated by the phenolsulphonephthalein test, was observed after the kidney pelvis was kept distended for from twenty to twenty-five minutes with molar sodium iodid, or fifteen minutes with 3 molar sodium bromid solution at the secretory pressure of the kidney. It will be noted that both the time of the distention and the pressure are several times as great as occurs in practice when pyelograms are made, i. e., if the medium is injected by the gravity method.

EXPERIMENT 3.—To duplicate, after a fashion, the situation resulting when the pyelographic medium is introduced into a kidney pelvis which fails to empty itself immediately, the right kidney pelvis in each of seven dogs was filled with 4/3 molar (17.5 per cent.) sodium iodid solution under 12 inches pressure. The amount of solution introduced averaged about 2 c.c. The ureter was then doubly ligated and divided. The right ureter in an eighth dog was doubly ligated and divided to serve as a control. All of the dogs survived until killed, and with no apparent harmful effects as far as general health was concerned. The first specimen of voided urine from the injected dogs showed a strongly positive test for iodin in each case. The test remained positive for at least twenty-four hours, no test being made at later times. After the injections, the animals were killed at periods varying from forty-five minutes to seventy-five days. The kidneys were removed and the contents of the right pelvis tested for the presence of iodids. The test for iodids in the pelvic contents of the ligated kidney was negative in the five dogs that were allowed to live two hours or over after injections. Iodid was present in the two specimens obtained from dogs killed in forty-five minutes and one and one-half hours, respectively. The rate of absorption was not thoroughly investigated, but in instances in which there was good diuresis and when the iodid solution had been introduced into the right kidney pelvis with a syringe and probably under higher pressure than usual, iodid appeared in the urine excreted by the left kidney five minutes later. At other times, however, when the right kidney pelvis was kept distended with the iodid solution under an even pressure up to the secretory pressure, no iodid was found in the urine from the left kidney excreted in from fifteen to twenty minutes after the injection.

The absorption from a hydronephrotic kidney was also tested. The animal, whose right ureter had been occluded for seventy-five days, was found to have a large palpable tumor appearing in the right upper part of the abdomen. This was found to be a hydronephrotic kidney sac containing 450 c.c. of fluid under 9 inches of pressure—about one third or one fourth of the normal secretory pressure found. The fluid was evacuated through the ureter. Following intravenous injection of saline and hypertonic glucose solution, the left kidney showed a good diuresis, but no fluid was excreted by the right. At this time 50 c.c. of 4/3 molar (17.5 per cent.) sodium iodid solution was introduced into the hydronephrotic sac which was, thereby, only slightly distended. Urine collected from the left kidney in ten, fifteen and twenty minutes showed iodid in rapidly increasing amounts, and in much greater concentration than found previously when the iodid solution was introduced into normal kidney pelves.

COMMENT

I do not now intend to advocate the use of potassium iodid solution for pyelography; but in view of the rapidity of absorption of substances from the kidney pelvis and the well-known toxicity of potassium

Fig. 3 (Miss H).—Left pyelogram with four-thirds (17.5 per cent.) solution of sodium iodid. Distinctness of minor calices may be noted, and their shape compared with that in Figure 4.

salts when given intravenously, the effect of the introduction of strong potassium iodid solution into the hydronephrotic sac was tested.

Thirty c.c. of a 25 per cent. solution of potassium iodid was introduced into the hydronephrotic sac which had been evacuated of all contents. A blood pressure tracing taken for the following ten minutes showed no circulatory changes. Likewise, no toxic effects of any kind were noted when a normal kidney pelvis was kept distended with a 25 per cent. solution of potassium iodid under 34 inches of pressure for a period of twenty minutes. As a matter of fact, in order that toxic

Fig. 4 (Miss H).—Right pyelogram with 17.5 per cent. sodium iodid solution. History of repeated right-sided kidney colic.

effects should be produced, the absorption of potassium iodid from the kidney pelvis would have to be more rapid than from the gastro-intestinal tract.

Pathologically, the kidneys whose pelves had been injected and whose ureters had been ligated showed very marked changes which varied in degree with the time elapsing after the ureteral occlusion, and showed all stages of hydronephrosis. But any changes which might have been due to the presence of sodium iodid were completely

overshadowed by the effects of occluding the ureter, since the changes following occlusion of the ureter alone could not be distinguished from those in which sodium iodid solution had also been injected.

This series of experiments shows that animals may live in apparently good health after the function of one of two normal kidneys has been lost by occlusion of its ureter, and that a 4/3 molar (17.5 per

Fig. 5 (Miss C).—Right pyelogram with 17.5 per cent. sodium iodid solution; thin patient.

cent.) solution of sodium iodid introduced into the pelvis of the kidney whose ureter has been occluded is absorbed, as a rule, in about two hours and causes no apparent harm, similar results being noted by Burns and Weld when other solutions were used. Rough quantitative tests also showed in the one case investigated that the total amount of sodium iodid absorbed in a given time from a large hydronephrotic sac filled with the iodid solution was much greater than the amount

absorbed in the same time from the pelvis of a normal kidney whose ureter had been occluded and which had been filled with iodid solution of the same strength. The absorption of potassium iodid from the hydronephrotic sac containing 30 c.c. of a 25 per cent. solution was not sufficiently rapid to cause apparent circulatory changes, nor were there any effects noted when a normal kidney pelvis was kept distended with a 25 per cent. potassium iodid solution under 34 inches of pressure.

TOXICITY OF MEDIUMS GIVEN INTRAVENOUSLY

The true tests of toxicity of pyelographic mediums should be made by determining the effects of these solutions when introduced into normal and diseased kidneys or ureters. However, it adds somewhat to the factor of safety if these solutions are not toxic when introduced directly into the blood stream in such amounts and concentrations as might occur from absorption from the kidney pelvis or might result from the accidental use of too great pressure in injection of the solution into the pelvis.

In the first experiment, a dog weighing 34 pounds was used. The intravenous injection of 5 c.c. of a 4/3 molar sodium iodid solution in thirty seconds caused no changes in the blood pressure curve. The subsequent injection under the same condition of the same amount of 3 molar sodium bromid and of the standard thorium solution was likewise without effect. The injection of 5 c.c. of molar potassium iodid solution caused a definite fall in blood pressure with gradual recovery. The experiment was repeated on the same dog, 16 c.c. of each solution being given in forty-five seconds. The injection of the 4/3 molar sodium iodid and of the 3 molar sodium bromid was without effect. Following the injection of the thorium solution, a very definite fall in blood pressure occurred, with gradual recovery. The dog died in fifteen seconds after the beginning of the injection of the molar potassium iodid. In other experiments, the amount of bromid and iodid solution given was considerably increased. No marked effects were caused when 50 c.c. of a 25 per cent. sodium iodid solution were injected in eight minutes in a 25-pound dog, the blood pressure curve rising slowly. The same amount of a 25 per cent. sodium bromid solution was given in ten minutes in a 30-pound dog, without apparent effect, thus confirming the result obtained by Weld. This dog died following the injection of 2 c.c. of 25 per cent. potassium bromid solution.

From this series of experiments, it is seen that 25 per cent. solutions of sodium iodid and sodium bromid, given intravenously in amounts up to 50 c.c. in 30-pound dogs produce very little immediate effect. It will be noted that this iodid solution is of nearly twice the concentration

which is recommended for pyelography. The standard thorium solution is relatively nontoxic, but definitely more toxic when given intravenously than either the sodium iodid or sodium bromid solutions. Potassium salts, as has long been known, are very toxic when given

Fig. 6 (Mrs. R).—Triple pyelogram with 17.5 per cent. sodium iodid; thin patient. Fused kidney with two pelves and ureters on the left. The condition was first diagnosed and the three ureters catheterized by Dr. F. R. Wright.

intravenously. It should be noted that in his comparative toxicity tests with sodium bromid, Weld used potassium iodid throughout instead of sodium iodid; and the marked toxicity of potassium iodid intrave-

nously, which he commented on and on which he based his serious objection to the use in general of iodids in pyelography, is due to the potassium ion.

It may be noted in passing that intraperitoneal injection of 20 c.c. of molar sodium iodid, 3 molar sodium bromid and standard thorium solution showed no constant differences in their effects produced within the two hours following the injection.

In general, the pure sodium iodid and bromid solutions were found to be strikingly nontoxic. It is probable, however, that these and the potassium salt solution, if desired, could be made still less toxic by the addition of small amounts, in correct proportion, of other salts, e. g., of calcium or magnesium, which Jacques Loeb,[18] Mathews [19] and others have shown to have a marked antagonistic effect on the toxicity of potassium and sodium ions. On the whole, the experiments made show that there is no marked difference in specific toxicity of iodids and bromids, the cation being the same, when solutions of the same percentage concentration are used. Of course, it must be noted that a 25 per cent. iodid solution has a much lower osmotic pressure than a similar 25 per cent. bromid solution; also that a 25 per cent. iodid solution is much more concentrated than that recommended for pyelography. Very detailed experiments in the toxicity of different anions and cations in relation to their solution tension and its relation to osmotic pressure are reported by Mathews.[20] The iodid ion is considered only slightly more toxic than the bromid ion.

OSMOTIC PRESSURE

The other possible cause of toxic effects resulting from the use of these solutions is their osmotic pressure. Of the several ways in which osmotic pressure of solutions may be determined, the most feasible for the solutions concerned is the freezing point method. Very accurate results may be obtained. The osmotic pressure of a solution is directly proportional to the depression of the freezing point below that of the pure solvent. The solutions tested were those used in the experimental work already reported. The depression of the freezing point of the iodid and thorium solutions noted in Table 3 is twice the value found for the solutions diluted with an equal volume of distilled water. This involves a slight but negligible error.

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18. Loeb, Jacques: The Dynamics of Living Matter, New York, Columbia University Press, 1906.

19. Mathews, A. P.: The Toxic and Antitoxic Action of Salts, Am. J. Physiol. **12**:419, 1904-1905.

20. Mathews, A. P.: The Nature of Chemical and Electrical Stimulation, Am. J. Physiol. **11**:455, 1904; The Relation Between the Solution Tension, Atomic Volume and the Physiological Action of the Elements, ibid. **10**:290, 1904.

According to Jones and Bassett,[21] the freezing point of solutions of sodium iodid and sodium bromid of the same molecular concentration is approximately the same and the actual lowering is greater than the theoretical, owing to the formation of hydrates. For comparison, the usual values for the freezing point of blood and of a concentrated urine may be taken as —0.56 C. and —2.70 C., respectively. The value for a very concentrated urine is considerably higher.

It is evident from these data that the molar solution of sodium iodid has a somewhat higher osmotic pressure than a concentrated urine, but in this respect comes much nearer than any of the other solutions to fulfiling the ideal requirements. It will be noted that the bromid solution has an osmotic pressure more than three times that of the iodid. This fact is of considerable importance, for it is well known that tissues are injured by being exposed to hypertonic solutions.

TABLE 3.—Freezing Points of Iodid and Thorium Solutions*

Solution	Freezing Point, Degrees C.
Sodium iodid, molar (13.5%)	—3.78
Neutral thorium, standard, Prep A	—5.52
Neutral thorium, standard, Prep B	—5.61
Sodium bromid, 3 molar (25.2%)	—13.47

* The value for 3 molar sodium bromid given is calculated from the data given by Jones and Getman (Ueber das Vorhandensein von Hydraten in konzentrierte wässerige Lösungen von Electrolyten, Ztschr. f. physik. Chem. 49: 385.

IRRITATION

The pain or discomfort which might be caused by the action of various solutions on sensory nerves of the kidney pelvis and ureter is somewhat difficult to determine, owing to the fact that the pain may be caused by one or more of several other factors, such as the catheterization alone or the overdistention of the kidney pelvis. It is well known that the pain during and after cystoscopy and ureteral catheterization alone may be quite severe. Again, the intrapelvic pressure need not be higher than the secretory pressure of the kidney under certain circumstances to cause colic. Therefore, pain during or following pyelography must not be attributed to the nature of the pyelographic medium unless the other causes are definitely known to be absent. Also, increasing experience shows that overdistention of the kidney pelvis, even though the gravity method is used, is a frequent cause of discomfort.

21. Jones and Bassett.: The Approximate Composition of the Hydrates Formed by Certain Electrolytes in Aqueous Solutions at Different Concentrations, Am. Chem. J. **33**:534, 1905.

The relative sensory stimulation produced by the various pyelographic mediums on tissue supplied with special sensory nerves can be easily determined. Very definite and striking results are obtained when the tongue is immersed in the various mediums. The standard

Fig. 7 (Mrs. R.).—Upper pelvis on left filled with 19 per cent. sodium iodid solution. Shadow of two stones and lower pole of the kidney distinctly seen.

neutral thorium solution which has a high sodium citrate content in addition to the thorium nitrate is surprisingly mild to the tongue and almost tasteless. A molar solution of sodium iodid has a distinctly

saline taste and causes no further apparent stimulation, even when the tongue is kept immersed in it for some time. The 3 molar sodium bromid solution, which Weld advocated as being quite bland, causes a definitely more intense stimulation on the tongue, at least, than that produced by the sodium iodid solution. It was found, however, that solutions of potassium salts were always distinctly more irritating to the tongue than solutions of the same concentration of sodium salts. This fact was overlooked in testing the stronger solutions recommended in my first articles, and now constitutes one of the main objections to the use of either potassium iodid or potassium bromid solutions. The calcium and strontium salts which also were tested were more or less irritating to the tongue. It is obvious, of course, that the kidney pelvis, which is insensible to presence of urine, is not nearly so sensitive to chemical stimulation as the tongue.

VISCOSITY

The ease with which these various solutions flow through small catheters and spread and diffuse into the smaller calices of the kidney pelvis depends primarily on their viscosity.

TABLE 4.—Relative Viscosity of Various Solutions

Solution	Viscosity
Distilled water	28.0
Molar sodium iodid	29.0
3 molar sodium bromid	31.5
Neutral thorium	50.0

The viscosity of the solutions was determined by the viscometer used for blood work. The figures given in Table 4 represent the time in seconds required for the solution tested to flow from the graduated chamber through the capillary exit. These values represent the relative viscosity of the solutions noted. The whole apparatus and solution were immersed in a water bath kept at body temperature.

It is obvious from these results that distilled water and the iodid solution have approximately the same viscosity. The bromid solution shows a slight increase. The thorium solution is definitely more viscid. This is not so serious, but, nevertheless, is a definite handicap when the easy and rapid flow and diffusion of the solution under a minimum pressure is desired. From the figures given, it is seen that a given quantity of the iodid solution would flow into the kidney pelvis in much less time than would be required for the same quantity of the thorium solution, the pressure head being the same. In this connection, it must be remembered that the kidney is secreting urine continuously, and the concentration of the pyelographic medium in the pelvis is lowered in proportion to the time consumed in filling it. And thus the opacity o

the standard thorium solution which was determined experimentally in the test tube is considerably diminished in practice, through relatively greater dilution with urine in the kidney pelvis.

CLINICAL RESULTS

To Dr. A. C. Strachauer I am indebted for the opportunity of putting to practical use solutions of sodium iodid in pyelography, the work being carried out on the surgical service at the University Hospital, Minneapolis.

The results given here are based entirely on my experience in using for pyelography sodium iodid in concentrations varying from 20 per cent. to 13.5 per cent. in strength. In all, twenty-two pyelograms and ureterograms were made. At the beginning of the work the stronger solutions were used, but it was soon seen that the results were very good with weaker solutions, and lately the 13.5 per cent. solution has been used altogether. The results with it have been so satisfactory, even when it was put to a severe test in unusually heavy patients, that it seems probable that no stronger solution need ever be used, and in thin patients still weaker ones would suffice. It will be noted that a molar solution of sodium iodid is formed when 15 gm. of the salt is dissolved in a sufficient amount of water to make 100 c.c., and this will be found to contain 13.5 per cent. sodium iodid by weight. Likewise, the 17.5 per cent. and 4/3 molar solutions are identical and are formed by dissolving 20 gm. of salt in a sufficient amount of water to make 100 c.c.

The pyelograms obtained were uniformly good. They were all made with the ordinary gas tube, the alternate spark gap varying from 4 to 4½ inches. For the excellent roentgenographic work displayed in making the pyelograms as well as in the investigation of the relative opacity of numerous solutions, credit is due Miss Bagamill of the University Hospital. The average quality of the pyelograms is shown in the accompanying illustrations, which do not represent in any way exceptional results, for the pyelograms illustrated, with the two exceptions noted, were obtained with patients well above the average in weight. The solution was always injected by the gravity method, the exposure being made while the kidney pelvis was being filled. The apparatus described by Thomas [22] is well suited for this purpose. In this connection it is well to emphasize the point made by several men that the technical results are very much better if the exposure is made while the kidney pelvis is still being filled. This point must not be overlooked if good results are desired. On two occasions, I attempted to make a double pyelogram, using a buret with a single catheter

22. Thomas, G. J.: An Apparatus for the Injection and Lavage of the Pelves of the Kidneys and the Ureters, J. A. M. A. **60**:184 (Jan. 18) 1913.

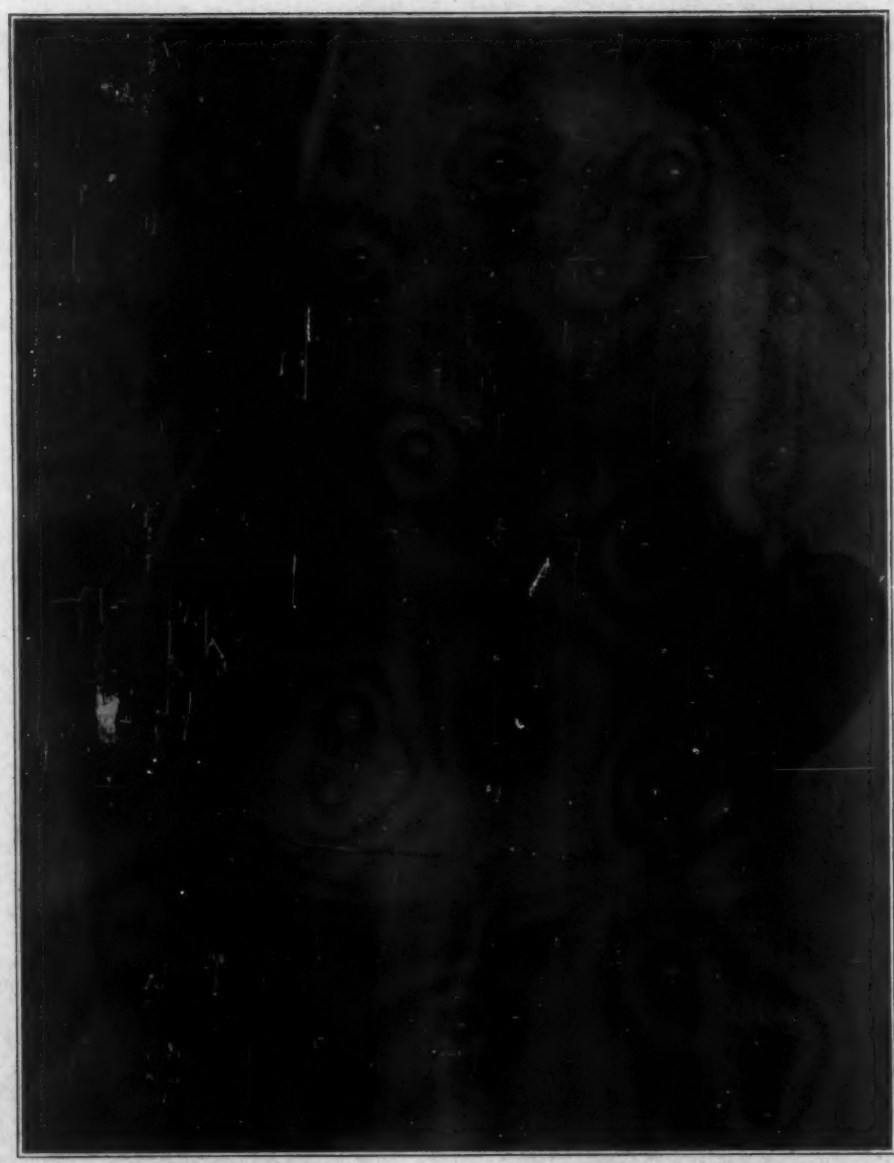

Fig. 8 (Mrs. R.).—Left lower ureterogram. Irregular shadows, shown near the bladder in the original roentgenogram, are localized by this ureterogram. The patient subsequently passed four small stones spontaneously. It will be noted that the upper pelvis of this kidney and its ureter were free from stones. A 17.5 per cent. sodium iodid solution was used.

needle. After the first pelvis was filled, the catheter was occluded by a small wooden cork and the needle transferred to the other catheter. In each instance, the technical result was poor on the side first filled. The amount of solution introduced into the kidney pelvis varied from 4 to 10 c.c., the least amount introduced (4 c.c.) of the 4/3 molar solution represented the capacity of a polycystic kidney pelvis, and an excellent pyelogram was obtained. In no case in my rather limited experience with the molar solution has a poor pyelogram resulted as the result of insufficient opacity of the medium. But if experience should show that a more opaque medium is desirable at times, it should be remembered that the 4/3 molar (17.5 per cent.) solution of sodium iodid may be used with perfect safety, and that it is much more opaque than either the 25 per cent. bromid or standard thorium solution.

To determine the amount of discomfort or pain produced, the patients were carefully observed and questioned while the pyelograms were being made and afterward. A reasonable allowance was made for the distress occurring after cystoscopy and ureteral catheterization alone. The results may be thus summarized: In no instance was there any increase whatever in discomfort noted or complained of while the first 4 or 5 c.c. of any of the iodid solutions used were being introduced into the kidney pelvis. Several patients, on whom differential functional tests had just been made, were unable to distinguish any new sensations whatever, either during or subsequent to the filling of the pelvis. Figure 2 is a pyelogram of such a patient, in whose kidney pelvis 10 c.c. of the molar solution was introduced. A few of the patients began to have increasing distress when the injection was continued after 4 or 5 c.c. of solution had been introduced. In view of the absolutely painless procedure in a number of cases, I am convinced that the distress in these instances was caused entirely by overdistention of the kidney pelvis, it being evident that only a small amount of solution might cause an overdistention of a pelvis which, at the same time, was being rapidly filled with urine. It was soon learned, as has been especially emphasized by Braasch,[23] that the injection should not be carried so far as to produce pain; thus far, the small amount of solution injected painlessly in such cases has been sufficient to outline the pelvis, though it is evident this might be unsatisfactory if one were dealing with a hydronephrosis. During the twenty-four hours after pyelography, some of the patients have complained of distress, occasionally quite severe, felt in the kidney region and along the ureters, but this trouble, except in those who had had an evident overdistention of the kidney pelvis, could be considered no more severe than that occasionally produced by ureteral catheterization alone. On the whole,

23. Braasch, W. F.: Pyelography, Philadelphia, W. B. Saunders Company.

it may be stated that no increased discomfort is caused by the introduction of a molar, or 4/3 molar, solution of sodium iodid into the human kidney pelvis, provided no overdistention is produced.

It was also considered of interest to determine what changes, if any, are produced on the function of the human kidney, the pelvis of which has been filled with the iodid solution. It will be recalled that this procedure had no effect on the kidney function in the dog. In Table 5, the total renal function before and after double pyelography is given. The total functional change after single pyelography is not given, as it would be of little significance, since an appreciable damage to one of two good kidneys might produce little or no change in total function.

From these results it is evident that the use of sodium iodid in pyelography causes no diminution of renal function demonstrable by the ordinary functional tests.

TABLE 5.—Total Renal Function Before and After Double Pyelography

Patient	Original Phenolsulphonephthalein Excretion, per Cent.	Procedure	Solution Used, per Cent.	Phenol-sulphone-phthalein Excretion Afterward, per Cent.
Mr. S.	45	2 double pyelograms	17.5 13.5	43
Mrs. R.	..	2 triple pyelograms	17.5	64
Miss V.	75	Double pyelogram	17.5	72
Miss D.	65	Double pyelogram	17.5	71
Mrs. W.	Blood urea nitrogen, 12 mg.	Single pyelogram; other ureter occluded	17.5	11.5 mg.
	Creatinin, 1 mg.	.....	....	0.85 mg.

CHOICE OF SOLUTIONS

In view of the effect of colloidal silver solutions on the renal parenchyma, as has been shown by various reports in recent medical literature, their use should be discontinued. Braasch and Mann,[3] in particular, have reported the results of comparative study of the effect of various mediums on the kidney. In addition to their toxic effects, they are expensive, viscid, possess undesirable physical properties, and are unstable in the presence of urine.

In being free from toxic and irritating effects and in giving fairly good technical results, the neutral thorium solution recommended by Burns is entirely satisfactory so far as I am aware. The fact that it had been used at one hospital in more than 500 cases as reported by Burns, and without any untoward results, is sufficient evidence as to its usefulness. One objection to its use is that the solution is prepared with some difficulty and is somewhat expensive if the prepared solution is purchased. To begin with, thorium nitrate is not a common salt

and often can be obtained only on a special order, and even then from only a limited number of large chemical houses. After the salt is obtained, a considerable amount of concentrated sodium citrate solution is required to redissolve the thorium which at first is precipitated. The citrate solution so prepared must be made neutral by the addition of the proper amount of alkali. However, this solution, as has been shown, possesses certain disadvantages. Of greatest importance is the fact that it is much more viscid than the iodid solution, requiring over 50 per cent. more time for a given quantity to flow through the small tube of a viscometer. For this reason, under the same pressure much more of the iodid solution may be introduced into a kidney pelvis, for part of the capacity is always taken up by the urine excreted while the injection is taking place. Furthermore, the thorium solution has an osmotic pressure almost 50 per cent. greater than the iodid, and it is evident that the ideal solution should have an osmotic pressure still less than that of the iodid, at least not greater than that of a concentrated urine. The thorium solution is slightly, but definitely, more toxic than the iodid when given intravenously in dogs. In conclusion, it should be remembered that the molar iodid solution has an opacity distinctly greater than that of the standard thorium preparation and, in practice, seems to me to give greater contrast on plates, owing equally to its lower viscosity and greater opacity.

The 25 per cent. sodium bromid solution, which was recommended for pyelography by Weld some time after I had published two articles on the use of iodids for this purpose, naturally possesses many of the desirable features of the iodid solution. The chief advantages claimed for the bromid solution were that it was much less toxic than potassium iodid when given intravenously, and that it is much less expensive than any of the other mediums. It was also stated that in the same percentage concentrations the bromid and iodid solutions were of about equal opacity. These statements and their bearing on the selection of the most suitable medium for pyelography will be considered in greater detail. To begin with, the conclusion regarding the relative opacity of the bromid and iodid solutions is entirely erroneous. The fact that, when exposed to roentgen rays of the character of those used in pyelography, a molar (13.5 per cent.) solution of sodium iodid has the same, or greater, opacity than that possessed by a 3 molar (25.2 per cent.) solution of sodium bromid admits of no question. This has been established by my work as well as by previous investigations carried out by many physicists. And, in this connection, it is well to note again that there is no simple relation between the atomic weight of an element and its opacity to roentgen rays. It will also be noted that in his comparative toxicity tests, Weld used for the most part a 25 per cent. solution of sodium bromid against a 25 per cent. solution of potassium

Fig. 9 (Mr. S.).—Left ureterogram with 13.5 per cent. sodium iodid solution. A shadow near the bladder seen in the original roentgenogram was localized by this ureterogram and can be seen in this plate as a dense center surrounded by a less dense zone lying at the lower end of the dilated ureter.

iodid. Even so, very little difference was found in the effect of these two solutions on the kidney parenchyma itself. But the great toxicity of potassium iodid when given intravenously in concentrated solution was especially emphasized. The marked toxicity of potassium salts when introduced into the blood stream, in pure and concentrated solutions, has been known for many years. If Weld had tested potassium bromid, he would have found it to be practically as toxic as the iodid, and, likewise, if he had tested sodium iodid, which I had even recommended as preferable to the potassium salt, he would have found it about as nontoxic as the sodium bromid, there being no appreciable difference in toxicity between a 25 per cent. solution of sodium iodid and sodium bromid when given intravenously in dogs. It is obvious, however, that for comparable results the molar (13.5 per cent.) sodium iodid and the 3 molar (25.2 per cent.) sodium bromid solutions must be used. When given intravenously, these solutions are relatively nontoxic, and when introduced into the kidney pelvis cause no apparent changes or diminution of function as shown by the usual tests. The question as to which of these two solutions is the better for pyelography probably will be established only after long experience. It is true that, as far as expense is concerned, the bromid solution would be preferable. A given volume of the bromid solution can be prepared at a cost much less than that of the same volume of iodid solution of the same opacity. However, at present, 200 c.c. of the iodid solution costs about $0.45; and, since on an average the amount of solution used for a pyelogram will not exceed 10 c.c., the cost is seen to be quite moderate and should not be a great factor in the selection of mediums unless they are to be used in very large quantities.

There are, however, several more or less valid reasons why, it appears to me, the iodid solution should be preferred:

1. It is very probable that the iodid solution is less irritating to a kidney pelvis than the bromid. At least, it may be stated definitely that the tongue is subjected to a more intense stimulation by the bromid solution.

2. It is very probable, though not definitely proved, that the molar iodid solution is less toxic to tissues in general, including kidney parenchyma, than the 25 per cent. bromid. The reasons for this statement are: first, a 25 per cent. solution of sodium iodid given intravenously in dogs has apparently no greater toxic effect than a 25 per cent. sodium bromid solution and the molar iodid solution, which is used in practice, is still less toxic; second, the 25 per cent. bromid solution has an osmotic pressure over three times as great as that of the iodid. This is a very important difference, as it is well known that, other conditions being equal, the toxicity of a solution to living tissues, in general, increases with the hypertonicity. It happens that the cells of the

kidney tubules and of the pelvis are undisturbed by the presence of the hypertonic urine; but the molar iodid solution has a still somewhat greater hypertonicity than urine and, in that respect, fails to meet the requirements of an ideal medium, and by so much the more does the bromid solution fail to meet this requirement.

3. The third quite real advantage possessed by the iodid solution is its marked relative increase in opacity to the roentgen ray as penetration increases. Physicists have commented on this property of iodin and have placed it in a group of elements exhibiting so-called selective absorption. This is of great practical importance in this way. Most of the technical difficulty in obtaining good pyelograms occurs in patients who have a great anteroposterior diameter at the level of the kidney, thus necessitating the use of greater roentgen-ray penetration. Under such conditions, the iodid solution casts a shadow which increases relatively in density as the penetration increases, while the bromid solution becomes relatively much less opaque. Therefore, to produce a shadow of the same relative density, a much stronger solution of the bromid must be used.

SUMMARY OF RESULTS

1. The investigation of the comparative opacity of several pyelographic mediums shows that the molar, or 13.5 per cent., solution of sodium iodid is fully as opaque as the 3 molar, or 25.2 per cent., solution of sodium bromid and is definitely more opaque than the standard neutral thorium solution, which is correctly designated as a 5/16 molar thorium nitrate solution, but is commonly called the "15 per cent." solution.

2. The kidney function as determined by the usual blood urea nitrogen and creatinin and by the phenolsulphonephthalein tests, both in the dog and in man, is not changed by the introduction of the molar and 4/3 molar solutions of sodium iodid into the kidney pelvis even when, experimentally, the latter was kept distended by the solutions at the secretory pressure of the kidney for twenty-five minutes. The same results were also obtained with the 3 molar sodium bromid solution.

3. When given intravenously in dogs, the 25 per cent. sodium iodid, as well as the 25 per cent. sodium bromid solution, produces no apparent immediate toxic effect. The blood pressure and respiration have remained unaffected when 50 c.c. of each of these solutions has been injected intravenously in a 30-pound dog within a period of ten minutes. The 13.5 per cent. sodium iodid solution, however, is the solution used for pyelography. Solutions of potassium salts, whether bromid or iodid, are very toxic when given intravenously, a fact long known.

4. The comparatively rapid absorption of different substances from the kidney pelvis, as observed by Burns and Weld, is confirmed by the fact that the contents of the kidney pelvis of a dog one and a half to two hours after it has been filled with a molar or 4/3 molar sodium iodid solution, which was retained in the pelvis by occluding the ureter, fails to respond to the usual chemical tests for iodid.

5. The sensory stimulation or irritation of the kidney pelvis produced by the three different mediums investigated is probably very slight, but marked differences are obvious when tested on the tongue, the thorium solution causing the least stimulation and the 25 per cent. bromid, the greatest.

6. The viscosity of distilled water, the molar sodium iodid, the 3 molar sodium bromid and the standard thorium solutions, as determined by the ordinary viscometer, is represented by the figures 28, 29, 31.5 and 50, respectively. A low viscosity is a very important property for a good pyelographic medium, since the quantity of the medium which can be introduced into the kidney pelvis, other things being equal, varies inversely with the viscosity.

7. The osmotic pressure of an average concentrated urine, of the molar sodium iodid, the 3 molar sodium bromid and the standard thorium solution is represented by the figures 2.7, 3.78, 13.47 and 5.52, respectively. From this it is evident that the iodid solution is the least hypertonic of the three mediums, and in this respect is far nearer the ideal than the bromid solution which has over three times as great an osmotic pressure, for it is well known that, other things being constant, the injury produced by hypertonic solutions on living tissues increases with the hypertonicity.

8. For clinical use I have personally made twenty-two pyelograms, using sodium iodid varying in strength from 20 to 13.5 per cent. No serious reactions whatever have been seen. The number of patients who had more or less distress as a result of the pyelography is equaled by the number who suffered no additional discomfort whatever, and I am convinced that the additional discomfort was caused by overdistending the kidney pelvis.

9. In the light of the foregoing experiments my previous conclusions are modified in two respects: First, in the article that I published in collaboration with Grandy, sufficient emphasis was not placed on the fact that the sodium iodid solution was preferable to the potassium, for it has been shown that the potassium salt is somewhat irritating and, in addition, because of its toxicity when given intravenously, it does not afford so great a factor of safety in the event of its absorption in large amounts. Second, increasing experience has demonstrated that instead of the 25 per cent. solution of sodium iodid originally recommended, a molar or 13.5 per cent. solution has been found to be sufficiently

opaque for all pyelographic work, and in this respect, at least, it equals and, when penetrating rays are used, always surpassed the 25 per cent. bromid and the standard thorium solutions.

10. The molar, or 13.5 per cent., sodium iodid solution now recommended is prepared by dissolving 15 gm. of the salt in a sufficient amount of water to make 100 c.c. In previous articles I have shown that such a solution is neutral in reaction, mildly saline to taste, nonirritating, and does not form precipitates with blood or urine.

11. In conclusion, although the molar sodium iodid solution is not the least expensive of the pyelographic mediums, it nevertheless possesses certain distinct advantages which seem to me, at least, to make it the most suitable. Among these should be emphasized its freedom from toxic effects and irritation, as far as can be determined, its ease in preparation, the fact that it has the lowest viscosity and the lowest osmotic pressure of any mediums so far suggested, colloids and emulsions alone excepted, and the fact that it exhibits an opacity to roentgen rays which actually increases relatively with increasing penetration of the rays, definitely surpassing, in this respect, the thorium and bromid solutions.

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